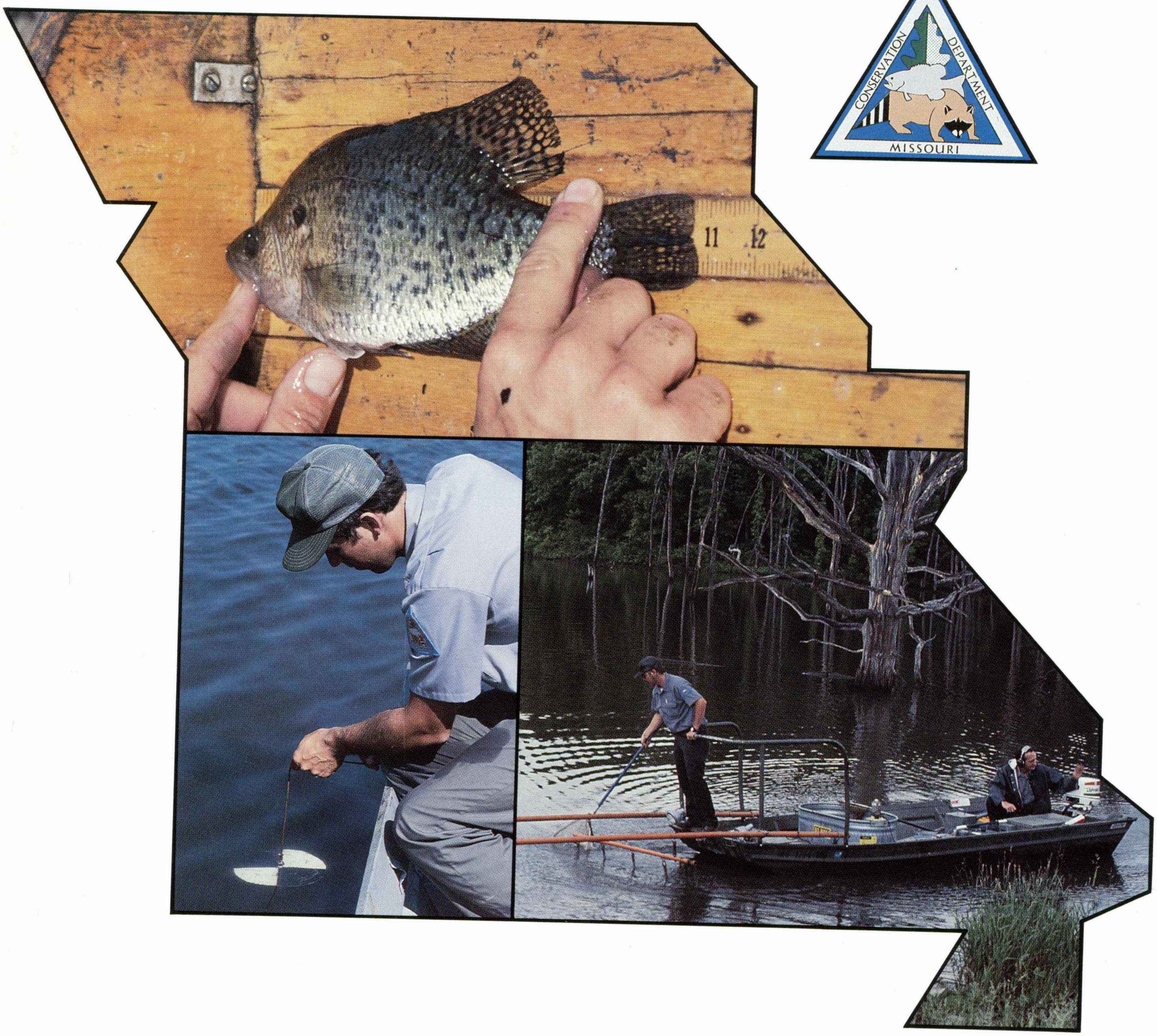
FISHERIES MANAGEMENT



Conservation Education Series

A Program of the Missouri Department of Conservation

The Missouri Department of Conservation

The Conservation Commission is by law, the head of the Department of Conservation, which is responsible for the control, management, restoration and conservation of all wildlife and forest resources of Missouri. The Commission appoints the Director, sets Department policy and approves budgets, regulations and real estate transactions.

The Department was created by an amendment to the Missouri State Constitution. The four Commissioners are appointed by the Governor of the state for staggered terms of six years and must be confirmed by the State Senate. No more than two may be from the same political party. The Department is free of partisan politics and is widely considered a model conservation agency. The Department is financed primarily from the sale of hunting and fishing permits and a 1/8 of 1 percent sales tax voted by the citizens of Missouri in 1976 to implement expanded conservation programs in the years ahead. The Department also receives federal aid funds from several agencies. Collectively, all funding sources support the broad-based programs of the Department, a state agency dedicated to public service and conservation.

As one of the 14 departments of the state government, the Conservation Department undergoes the same budgetary appropriation process and accounting and purchasing procedures as do other state agencies. Also, the Department is annually audited by the State Auditor as requested in 1977 by the Conservation Commission.

The Department has divisions responsible for Fisheries, Forestry, Wildlife and Protection programs. Other organizational units are responsible for Conservation Education, Engineering, Fiscal, Public Affairs, Natural History, Operations, Outdoor Skills Education, Personnel and Planning functions.

Instructional Unit

FISHERIES MANAGEMENT

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Missouri Department of Conservation
Conservation Education Unit
Education Section

Conservation Education Series

Conservation education encompasses all the activities and experiences which result in learning about people's dependency upon and use of natural resources to satisfy their needs and wants. Since 1941, the Missouri Department of Conservation has supported a *formal education program* through Missouri's public and non-public schools. This formal education program is being expanded with the development of the *Conservation Education Series.* The series will include instructional units designed to aid teachers in their efforts to integrate conservation concepts into appropriate junior and senior high school curricular areas.

The development of the *Conservation Education Series* is a formidable challenge involving many individuals. We are indebted to Director Larry R. Gale and Assistant Director Allen Brohn for their support and encouragement. We are also indebted to Donald K. Heard, superintendent of education, and Al Palladino, assistant superintendent of conservation education, for their guidance and assistance.

This series would not be possible without the contribution of each instructional unit's author and artist. Thanks to Elaine Callaway, conservation education consultant, and Cathy Schwaller, curriculum specialist, for their editing and production efforts. Special thanks to Louis Stephen Eder, fisheries management biologist, for providing information on current fisheries management methods in Missouri, and assisting with content and format editing, and to David K. Jennings, fisheries management biologist, for his assistance with the original development outline for the unit.

The *Conservation Education Series* is dedicated to the Department's conservation education consultants, past and present. This small group of men and women have recognized education as a vital and important force in resource conservation . . . and have accepted the challenge. The conservation challenge should concern all of us, but especially those charged with educating today's youth. We hope this series will aid Missouri teachers in meeting this challenge.

For additional information on conservation education programs, write the Education Section, Missouri Department of Conservation, P.O. Box 180, Jefferson City, MO 65102.

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The *Fisheries Management* Instructional Unit is designed to assist life science, biology, ecology, and resource management teachers in integrating fisheries management information and concepts into their resource conservation units. Though the basic understandings of fisheries management are universal, the text incorporates and stresses those concerns, methods, and techniques specific to Missouri.

The lesson plans, accompanied by suggested methods and activities, and audio-visual aids, are designed for use with junior and senior high school students. Provided in general format, without inclusion of a time element, they should be modified in content to meet the needs of

students, class, and teaching objectives. Objectives are listed for the unit in general and more specifically in each lesson plan. In addition, a sample unit test, sources of supplemental materials and activities, a glossary, and a bibliography are provided. Data sheets, transparency masters, and informational examples are included in the appendix for reproduction as student handouts.

The unit addresses the following Basic Essential Skills Test (BEST) objectives:

Reading/Language Arts #5, 12, 13, 16, 17, 21

Mathematics #1, 2, 6, 7, 8, 9, 11, 14, 15

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Introduction

Fishing in Missouri is a universal theme that transcends time, space, and human barriers. Regardless of race, creed, age, or sex, every Missourian can enjoy fishing. Today, sport fishing evokes pictures of recreation along clear, springfed Ozark streams, large meandering farm/country rivers, small farm ponds, and large reservoirs . . . the living waters of Missouri.

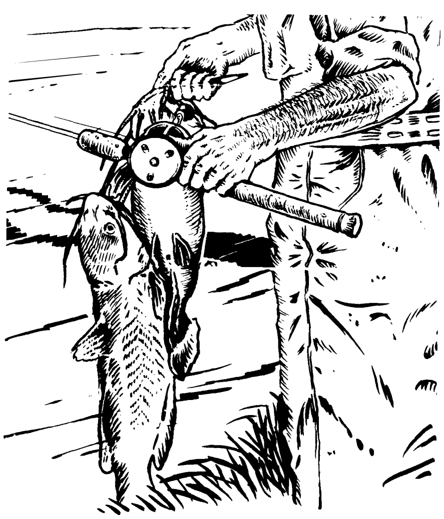
Importance of Fish and Fishing

Fishing is one of the major participatory outdoor sports in Missouri and the United States. Nationwide, about 53 percent of all Americans go fishing each year, compared to the 19 percent that go hunting.

Sport fishing survey

According to the 1980 "National Survey of Fishing, Hunting, and Wildlife-Associated Recreation," some 1.2 million Missouri anglers spent over 20 million days fishing, taking nearly 2.5 times as many trips as Missouri's 0.5 million hunters in the same year. Fishermen also accounted for most of the money spent on hunting and fishing in Missouri. In 1980 anglers spent $340 million on travel and equipment, surpassing hunter expenditures nearly two to one.

Value of fish



Fish rank high as a source of food for humans and are of considerable social and economic value. Anglers consider many species of special interest because they are fun to catch, thus lending them an indirect economic value. Still others are of no value for either eating or sport, yet serve as food for those species that people like to catch and eat.

Fishermen expect a fairly continuous supply of game fishes from the majority of the public and private waters of Missouri. Each stream, pond, or lake is a separate aquatic system, with its own chemical, physical, and biological characteristics. Besides environmental factors, various other conditions often affect the quality of the systems. It is the role of fisheries management to scientifically study each aquatic system and to devise and implement a management plan to produce and maintain good populations of quality sized game fishes.

Objectives of Unit

The general objectives of this instructional unit are that each student should be able to:

1. Explain the relationship between water quality and fisheries management.
2. Describe three methods of sampling fish populations.
3. Name three physical and three chemical characteristics of water that are of interest to fisheries biologists.
4. Explain the importance of watershed management to fisheries management.

5. Discuss the reasons for use of length limits and creel limits as regulations.
6. Explain how social pressures affect biological fisheries management.
7. List the scientific disciplines in which a fishery manager must have specific training, as well as the fields in which he/she must have a working knowledge.

Refer to individual lesson plans for more specific objectives.

Definition of Fishes

Fishes are coldblooded animals that typically have backbones, gills, and fins and are primarily dependent on water as a medium in which to live.

Where Fish Live

Members of the fish community constitute a diverse group. They live almost anywhere that there is water, both on the earth's surface and in surface-connected subterranean rivers. According to Lagler (1977), "Water is a highway, byway, communications medium, nursery, playground, school, room, bed, board, drink, toilet, and grave for a fish. All the fishes' vital functions of feeding, digestion, assimilation, growth, responses to stimuli, and reproduction are dependent on water."

Unique Characteristics of Water

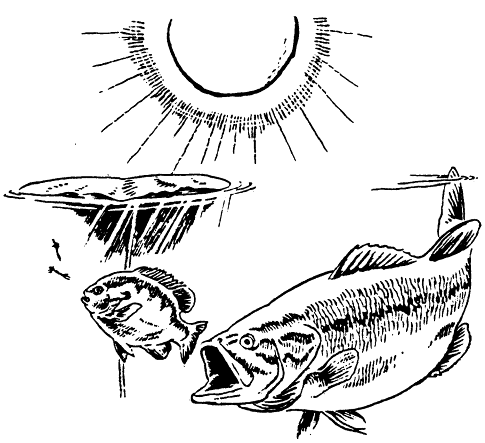
Heat of fusion = 80 calories/gram

Heat of vaporization = 540 calories/gram

Water is the only substance on earth that exists in all three physical states under natural conditions. Unlike other substances which increase in density as they change from a liquid to a solid, water reaches its maximum density at 39°F (4°C), slightly above freezing temperature. As it begins to freeze, it becomes less dense than liquid water. This unique characteristic of water causes ice to float. If this were not the case, ice would form from the bottom to the top in freshwater lakes, ponds and streams, killing most of the organisms present.

As the universal solvent, the dissolving power of water is greater than any other liquid. It is capable of transporting countless materials, from dissolved oxygen and other gases, upon which the life of a fish ultimately depends, to harmful pollutants and toxins.

Water is also a buffer against extreme temperature fluctuations. Rapid temperature changes, which would quickly destroy fish and other aquatic organisms, are prevented by water's high heat retention capacity. Each gram of water is capable of gaining or losing one calorie for each celsius degree temperature change. More heat is required to change water's temperature at the freezing and boiling points when additional attractions between molecules are involved. (For more information see a chemistry text about heat capacity and latent heats.)



Energy Transfer in Aquatic Ecosystems

As on land, life in water is dependent on the transfer of light energy from the sun to producer organisms (green plants). Because of the transparency of water, sunlight filters into the system where phytoplankton, larger algae, and submergent green plants are able to harness it and produce food for the consumer levels through the process of photosynthesis. Energy is then transferred from animal to animal, as each level is consumed by another.

Fisheries Management: General Concerns

Fishermen prefer a continuous supply of desirable game fishes, usually large predators that are at or near the top levels of the food chain. Yet, according to the pyramids of numbers, biomass, and energy, large predator fishes are the least numerous in the total system. Their numbers must be maintained with scrutiny. Their removal can lead to ineffective predation, overpopulation, and stunting of lower levels of prey fishes. An imbalance of the man-desired fishery results.

Regardless of how much data the fisheries manager might collect, nature remains a dynamic entity.

Natural Environmental Factors

Since every body of water is different, a myriad of factors impinge upon one another to affect the production of even a single species of fish. Fisheries managers are concerned with those environmental factors previously discussed, as well as characteristics of the lake, pond, or stream (size, depth, water level, substrate, shoreline structure, and watershed).

Dynamic Ecosystems

All aquatic communities are constantly changing and evolving through ecological succession. The dynamics of aquatic ecosystems are influenced physically and chemically by the properties of water. Also, species composition, predator/prey relationships, food supply, numbers and sizes, fecundity, and mortality of fishes vary as environmental features of the system favor or disfavor their needs.

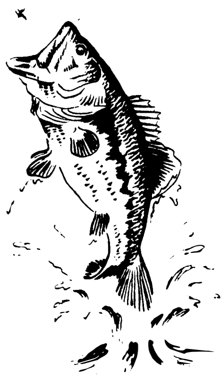
Societal Pressures

Decisions become even more complex when societal pressures are interjected into the fishery management "ball of wax." Influences on a body of water that may be beyond the biologist's control include: recreational boating and swimming, hydroelectric power, water storage, navigation, sewage effluent, irrigation, channelization, acid rain, and watershed land use.

Water: The Alien Medium

Water, as the medium in which fishes exist, adds yet another stumbling block to fisheries management. Unlike the terrestrial wildlife biologist, who lives on the earth in the very air shared by the animals that he is studying, the fisheries manager is alien to the water that he is attempting to understand.

Professional Training



Juggling all the factors involved in maintaining an angler's favorite fishing hole full of his favorite fish is tricky business. Competent fishery managers must have developed specific biological training in scientific disciplines such as ecology, aquatic botany, entomology, invertebrate zoology, ichthyology, and fisheries management. They must also have attained a working knowledge of diverse fields including limnology, chemistry, geology, hydrology, statistics, surveying, and public relations. Fisheries managers often have to apply their technical training and experience with dashes of instinct and then wait to see if their hunches pay off.

Water Quality Assessments

Chemical and physical analyses of water reveal an aquatic system's potential to support aquatic life. Though each factor is measured and recorded separately, all interact to affect the overall water quality.

Chemical Factors

The absence or excess of many chemicals in water is important in determining the productivity of an aquatic system. Studies of dissolved oxygen, carbon dioxide, pH, and fertility usually provide the biologist with sufficient management information.

Dissolved Oxygen

Photosynthesis

$$6CO_2 + 6H_2O \xrightarrow{\text{light } e} C_6H_{12}O_6 + 6O_2$$

Respiration

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{e} 6H_2O + 6CO_2\uparrow$$

Like all animals, fish need oxygen to breathe. The oxygen used by fish in the process of respiration is obtained from molecules of free oxygen gas (O_2) dissolved in the water, *not* from the atoms of oxygen chemically confined in the water molecule (H_2O). Fish are able to extract the dissolved oxygen by passing the water through their gills in much the same way that terrestrial animals extract oxygen from air by passing it through their lungs. Dissolved oxygen (DO) normally gets into water by diffusion from air, by aeration of flowing water (especially in stream riffles and lake surfaces during winds), and as a byproduct of photosynthesis by aquatic plants (the chief source in most systems).

The maximum amount of oxygen that will remain dissolved in water is called its saturation level. The saturation level is a function of atmospheric pressure and water temperature. For example, lower elevations and colder temperatures allow water to hold more DO.

Daily Fluctuations

In small bodies of water, DO fluctuations are cyclic with the number of daylight hours. Plants, even microscopic ones, continuously use oxygen in cellular respiration. At night when photosynthesis ceases, DO levels are diminished. Thus, the lowest and most critical periods of DO usually occur in very early morning. During daylight hours, photosynthesis resumes and DO increases.

Seasonal Fluctuations

Dissolved oxyen levels are particularly important when considering a standing body of water over the seasonal changes of a year. Generally, low DO levels are more critical in small ponds and streams during periods of extreme, prolonged heat and low rainfall. Even fish that can tolerate low DO levels for a few hours may die when exposed for several days. If they do manage to survive abnormally low DO levels, they become stressed and more susceptible to disease and parasites. When summer DO levels are at or below three or four parts per million (ppm equal to milligrams per liter or mg/1) for temporary periods, warm-water fishes like catfish do not feed or grow well. Sustained summer DO levels at two ppm or below may lead to death, even of tolerant fishes like carp.

Seasonal Anaerobiosis

Eutrophication: enrichment with nutrients; an aging process naturally converting a lake to forest or grassland by succession; speeded up by enrichment with fertilizer runoff or human wastes.

Another seasonal influence of DO levels which causes catastrophic fish mortalities is anaerobiosis—the complete depletion of dissolved oxygen in an aquatic system. Summer fish kills are often associated with eutrophication which results in excessive plant growth in small, shallow ponds and streams. Decomposition of these dense growths of plants and animals (plankton) removes DO from the water, leaving a critical shortage for fish. Summer kills usually take place after several cloudy days during hot weather, but they may occur overnight. The fertile waters of north Missouri are often more susceptible to this condition.

A similar phenomenon, winter kill, commonly occurs in ponds and oxbows that have a great deal of shallow water and high organic content. The condition is normally precipitated by ice and heavy snow cover. Ice is translucent and allows sunlight to reach aquatic plants. However, when covered by snow, which is more opaque than ice, light penetration is prevented and plants die and decay, removing dissolved oxygen from the water in the process. Fish may then suffocate.

leafy pond weed

As a rule of thumb, the warmer the water the more dissolved oxygen is necessary for the increased activity of fish. Fishes vary in their DO needs according to species, age, activity, temperature, nutritional state, and stress level. Larger fish are also more susceptible to DO depletion than smaller ones of the same species.

Supersaturation

Oxygen saturation in percentage and effect on fish:

Above 130% - all fishes affected and none survive extended exposure

115-130% - fish mortality variable but does occur

110-115% - fish mortality insignificant

100-110% - acceptable limit of supersaturation

80-100% - excellent DO content for fishes

60-80% - suitable DO content

Below 60% - poor with water too warm or decomposition bacteria using up DO

Too much oxygen, or supersaturation, can be just as lethal as too little. This condition may occur when water tumbles over rapids: thus, it is often encountered along streams controlled by dams. Though the excess oxygen usually effervesces out rapidly, fish exposed to this condition often experience gas bubble disease and death. As fishes breathe, they take excessive oxygen into the blood, especially in the deeper, colder waters below the spillway where the gas is held in solution under pressure. When the fishes swim into shallower water, the DO comes out of solution, forming bubbles in the circulatory system and tissues.

Free Carbon Dioxide

Carbon dioxide (CO_2) is a colorless gas produced by the respiration of plants and animals and decomposer bacteria. At night, green plants cease photosynthesis (oxygen production), yet they continue to carry on respiration (carbon dioxide production). Thus, more CO_2 enters the water during darkness. During days of constant cloud cover, the use of DO by respiration of the total system may exceed that produced by reduced photosynthesis, compounding the high CO_2/low DO problem.

Respiration

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{e} 6H_2O + 6CO_2\uparrow$$

The amount of free carbon dioxide in water is very important in fisheries management, for it displays the single best criterion of environmental suitability for fishes. Usually, free CO_2 levels in excess of 20 ppm are regarded as harmful to fish; lower levels may be toxic to fish in water of lower DO content. In fact, high levels of free CO_2 are usually found in combination with low values of DO.

Acidity/Alkalinity

A pH range of 6.5-8 is best for fish and most aquatic organisms.

Determining pH values of water as an indication of its acidity/alkalinity level is a valuable tool for detecting pollution. While most fishes tolerate wide ranges and rapid changes of pH, they usually flourish within a rather narrow range for optimal reproduction and growth. With a renewed concern for the negative effects of acid rain on fish populations, particularly in the Northeast United States, the monitoring of lowering pH values of lakes and streams is important. Most fish die when the pH of the water falls below an acidic 4.

Fertility

Fertility effects on Missouri fish production

	lbs./acre	
	Largemouth Bass	Bluegill
North Missouri	100	400
Ozarks	25	75

Aquatic systems may have excellent water quality—minimum turbidity, no chemical or physical pollution, and a high level of dissolved oxygen—but may not be particularly productive for fish and other living organisms. In order for the small plant life (phytoplankton) to grow and effectively supply nutrients to the food chain, the system must be fertile. A naturally fertile pond provides the nutrients which circulate through the food chain to produce a greater biomass of fish.

Northern Missouri impoundments (artificial collections or storages of water) that receive nutrient-rich runoff from fertilized agricultural lands and rich native soils sustain much larger fish populations than similar ponds in the rocky Ozarks. Some of the most fertile waters of Missouri are the oxbows (cut-offs of rivers). The fish biomass in these systems build up to such high levels that their dissolved oxygen needs often become critical.

Other Chemical Factors

Many other chemical factors, often combining as synergists, are found in aquatic systems and affect fish and other life. Though not usually measured except in potentially troubled streams, ponds, or lakes, fisheries managers must be aware of their existence and potential harm or benefit. Some of these are: chlorine, chlorides, chromium, calcium and magnesium (hardness), nitrates and nitrites, ammonia, alkalinity (buffer), and phosphates.

Physical Factors

Together with the chemical factors, the physical characteristics are important in determining the ability of an aquatic system to adequately sustain fish populations.

Water Temperature

Since water temperature is directly influenced by the temperature of the air above it, both are recorded and considered. Dissolved oxygen content and other chemical actions in the aquatic system rely on water temperature.

Fishes are often grouped according to water temperature tolerances: coldwater fishes such as trout prefer 50-60°F (10-16°C), coolwater fishes such as walleye and muskellunge favor 60-70°F (16-21°C), and warmwater fishes such as largemouth bass and channel catfish prefer 70-80°F (21-27°C). Only tolerant fishes such as carp and bullheads can live long in water temperatures above 97°F (36°C).

Because of their physical properties, deeper bodies of water stratify or form layered zones according to temperature. As a result of the presence or absence of certain chemical or physical factors, such as optimal temperature or dissolved oxygen, within the layers, zones of plant and animal production are established. Fishes are also established vertically or layered according to zones providing their needs at any particular time throughout the lake.

As seasonal temperature changes affect the water temperatures of the lake, the thermal layers rise and fall, causing turnover. This redistribution of water temperatures, foodstuffs, dissolved oxygen, and other factors affects fish movement and presence. (Study "What Is Lake Turnover," *Missouri Conservationist magazine,* September, 1984, for a complete discussion of lake stratification and turnover).

Turbidity

Turbidity indications of water clarity and suitability for fish life in Missouri using the Secchi disc:

less than 12 inches - high turbidity; undesirable

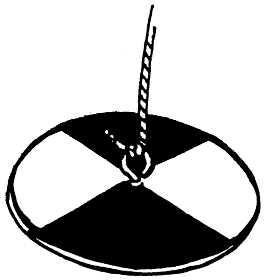
24-48 inches - optimal for fish life

over 60 inches - indicates system infertility

Turbidity (cloudiness) is caused by organic and inorganic agents suspended in water. These agents may directly harm fish, especially when heavy silt loads are carried during flood stages in rivers or ponds of agricultural areas. Silt can cover the eggs and clog the breathing apparatus of an aquatic organism, causing suffocation.

More importantly, turbidity reduces the amount of sunlight penetrating the water, thereby reducing photosynthesis and lowering overall productivity. Fish, such as bluegill and bass, that rely on sight for predation may be stunted or even die out due to reduced feeding opportunity. However, some predators such as flathead catfish and gar have adapted to high turbidity levels.

While a turbidimeter, a photoelectric cell, is used to check waters for a dissolved particle measurement, a simple Secchi disc is most often used for comparison. A Secchi disc is a 20 cm. circular plate with alternate quadrants painted white and black. It is lowered by a cord, marked to distinguish depths, until it cannot be seen. Thus the limit of visibility of waters can be compared in relative depths of light penetration.



Color

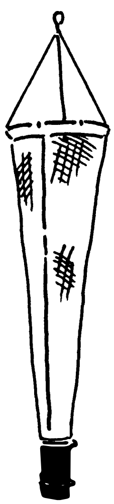
Water color may have much the same effect as turbidity. Phytoplankton may give the water a greenish tint and decomposing plants may turn it brown. In some cases color may be caused by the presence of certain chemicals in the water. In many instances, however, the toxic effects of the chemical are more important than the resultant color changes.

Other Physical Factors

Fisheries managers must also be alert to factors such as the presence and effects of coliform bacteria (a result of human sewage and feedlot runoff) and detergents, although these are not often encountered in Missouri.

Sampling Aquatic Organisms

Since it is difficult to observe aquatic organisms, fisheries managers must develop methods for sampling them. In order to assess the current presence and condition of the living organisms in a system, as well as the various species—their sizes, numbers, and foods in a pond, lake, or stream—biologists utilize a myriad of sampling techniques.



Plankton

Plankton is the major source of food for almost all species of fish at some period in their lives. The composition and abundance of plankton can be determined using specially designed nets.

Plankton nets are made of exceedingly fine (No. 20) silk mesh with a small container located at the constricted end. The mouth of the conventional plankton net (11.2 cm inside diameter) is attached to nylon cord so that when it is pulled through water, the plankton and other suspended solids are filtered into the container. (Specific methods of use and data handling are discussed in various methods texts).

Bottom Organisms

Benthic: *referring to the bottom of a body of water*

Benthos: *plant and animal life whose habitat is the bottom of a body of water*

Many aquatic organisms such as insects live in or on the bottoms of ponds, lakes, and streams. Since many species have narrow tolerances to chemical pollution, siltation, and enrichment, their presence is often a key water quality indicator. The numbers of bottom dwellers can be used as an index of available food for fish. Several samples are taken from different areas of a lake or stream to properly assess the benthic (bottom) community.

While bottom samples may be scraped from shallow water by a variety of simple means, special dredges—Ekman, Peterson, and others—are used in deeper waters. (Specific methods and data handling are discussed in methods texts).

Aquatic Vegetation

Besides providing the base of the fish food chain for the pond or lake, aquatic vegetation performs other functions. Many types of invertebrates that serve as food for small fishes are often located in submergent or emergent vegetation. Aquatic plants stabilize shorelines and provide shade, protection, and concealment. A rule of thumb in Missouri is that about 10 to 20 percent of a fishing pond surface should have aquatic plant cover.

Using plant hooks and rakes, biologists collect and record the types and relative abundance of aquatic vegetation. Using screens, the collected plants are washed to dislodge small invertebrates for identification.

Fish Sampling Methods

In most waters it is necessary to sample a complete cross-section of the existing fish population. Ideally, the fisheries manager would use a method that would sample large quantities of all species of fishes, in every size range, in a short period of time, during any season of the year, without stressing or otherwise hurting the fish. Since there is no one perfect method, the biologist must use an assortment of methods to cover all possible factors—habitat types, seasonal changes, various depths, and as many sizes of all fish species as possible.

Electrofishing

Using pulsed D.C. electricity from specially equipped boats or portable units, electrofishing stuns fish and draws them towards a positive electrode (galvanotaxis). The stunned fish are dipped from the water, held in aerated livewells for examination and measurement, and returned unharmed to the water.

Due to the ion and total dissolved solids content of different aquatic systems, electrofishing effectiveness varies. Most units do not effectively "shock" deep waters, so the researcher must use the apparatus when fishes move into shallow water in spring and late fall or early morning and evening during warmer weather.

Electrofishing also exhibits size bias. Lacking body density, small fish are not as conductive and not as easily stunned (electronarcosis) as larger fish. Thus, a given sample disproportionately reflects the larger sized fishes.

Species selectivity of electrofishing is an important consideration. Some kinds of fishes are more sensitive to boat noise and some are more mobile; thus they tend to avoid the electrical field in the water. Except with very selective methods, non-scaled species of fish are usually not captured in sufficient numbers to yield valid population data.

Biologists also have to be constantly alert to their own selectivity. Since the immobilized fish must first be seen (water clarity also plays a role in this), researchers must take care to capture not only the large predator species, but also the smaller prey species.

Gill Nets

Gill nets of varying lengths, heights, and mesh sizes—somewhat resembling a flexible chainlink fence—are usually made of relatively lightweight nylon thread or monofilament line. They

are typically weighted to catch fish on the bottom, although some are used as "floaters" to catch fish at all depths.

Gill nets normally capture fish by "gilling" them. The fish passes its head through a mesh too small to permit passage of the rest of the body. Once the gill covers have passed through, they catch on the net. The fish cannot back out or remove its head from the net. Catfish are often trapped by the serrated pectoral and dorsal fin spines, and fishes like bass may be trapped by the large jaw processes.

The mesh size of gill nets provides the greatest bias in species capture. Consequently, biologists may use a variety of nets with mesh sizes ranging from 2 to 4 inches to capture various sizes of fishes. Or they can key in on a specific species, such as using a net with 6- to 12-inch meshes to capture paddlefish. Gill netting is a passive capture method, rather than active like electrofishing.

Because of the method of capture, the researcher must frequently attend gill nets and remove the fish. Some mortality does occur, but the data gathered should outweigh the loss of a few fish. Catch rates using gill nets for more solitary fishes like catfish are usually lower when compared to electrofishing for bass; 10 fish per 12-hour period might be typical. Sightfeeding fish like bass appear to be able to see the fine thread in clear water and are not as vulnerable to capture.

Trap Nets

Trap nets use long panels of small mesh netting as wings or leads to block fish pathways. The leads direct the fish toward a cage through a series of net funnels that get increasingly smaller. These nets provide a passive method of sampling that causes almost no stress or mortality of fishes. Less demanding on the manager, trap nets can be attended daily and are usually placed so that they are fairly species-specific and rely on large numbers of fish traveling together (schooling) for maximum sampling effectiveness. They are often used to evaluate crappie or walleye in Missouri reservoirs and larger lakes.

Mid-water Trawls and Meter Nets

A meter net looks like an enlarged plankton net or a trawl, but is more heavily constructed. These nets are towed behind powerful stern drive boats in the open water (pelagic zone) of large reservoirs to sample the larval fishes (a few mm to 20 mm long). These nets are valuable in providing data about fish populations at their beginnings.

Most current Missouri research using meter nets is directed toward a better understanding of crappie and gizzard shad dynamics. The pelagic gizzard shad is a primary forage species in large lakes and, as yet, little is known about its population dynamics. The meter net is an important tool in studying this first level consumer.

Seines

While seines are not widely used as a standardized sampling technique by Missouri fisheries managers, some states use them extensively. A great variety of seines with various mesh sizes can be used selectively to sample some habitats.

The Common Sense Brand minnow seine—6 feet long, 4 feet deep, and of 0.125-inch mesh—is commonly used by fishermen for collecting bait fish and crayfish. A bag seine of longer length with a trailing bag is more effective for capturing small fish. In all cases a doubleweighted lead line keeps the bottom of the seine on the substrate while a float line buoys the top. While large seines may be mechanically moved through the water, most are drawn through the water by two people, one moving each end.

Seines can be effectively used in open, shallow streams and along shallow, non-vegetated edges of small ponds, yet their use has many drawbacks. Fishes easily detect the disturbances of people and seines in the water, and the large ones, unless trapped, avoid its sweep. Typical Missouri waters are also full of rocks, vegetation, and debris which interfere with a sweep, often rendering the seine ineffective.

Observation

Like other animals in natural habitats, some fishes can be observed successfully by the investigator that has the patience and the luxury of free time. Observations are almost totally dependent upon the clarity of the water.

Chemical

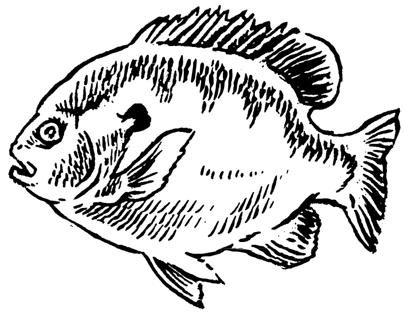
Chemical suffocants are most often used to totally kill out fish life for renovation of small ponds and lakes, however, they can also be effectively used under certain conditions to evaluate fish populations.

The substance most often used is a commercial chemical that contains rotenone. While the mixture is considered harmless to warm-blooded animals, it blocks uptake of the dissolved oxygen at the fishes' gills, killing them in a matter of minutes in warm water with temperatures of 70°F (21°C) and up. Caution must be taken for use in streams, and a detoxification compound must be applied to restrict the sampling to the target area.

On occasion, fisheries biologists use rotenone to sample selected small coves in large Missouri reservoirs. The study cove is netted off from the rest of the lake, a few fish are captured, marked, and released in the cove to determine pick-up percentages and size bias, and then the chemical is added only to the cove. Dead fish are then removed for counts and biological examination.

The basis of this method of capture is that data gathered also applies to the other coves of the impoundment. It provides a good estimate of total numbers, weights, lengths, and species composition. Compared to the total population of the lake, this small mortality is insignificant since valuable management data is accumulated.

Assessing Fish Populations



A major goal of fisheries management is to maintain an optimum sustained yield of desirable fishes. It is extremely important to know the makeup of the fish populations upon which a decided measure of fishing success depends. To achieve this objective, the biologist attempts to determine the growth rate, age composition, size composition, densities, recruitment, and mortality of the fishes in a system.

Age and Growth Studies

Knowledge of the age and rate of growth of a fish in a population is useful in management. While the actual processes of assessing age and growth rates are different, they are very closely related. Since the central theme is, "How long does it take a fish to attain a certain weight or length," the analyses are often called age and growth studies.

Many factors affect fish growth: variation in genetic stock, productivity of the water, availability of food items, and length of growing season. For example, largemouth bass of the same parent stock in fertile north Missouri waters may attain a 12-inch length in three years, but only grow to 10 inches in the same time period in less productive Ozark impoundments. Yet the longer growing season of the south may partially offset the lack of water fertility.

Thus each aquatic system must be evaluated according to its potential to determine:

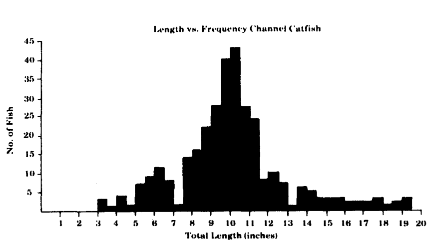
1. Is the population healthy?
2. Are the species growing well?
3. Is there a good size distribution?

Known Age Method

To evaluate growth potential, the fisheries manager may release marked fish of known age into natural waters. Upon recapture, the length/weight measurements provide accurate growth potentials for natural populations.

Length-Frequency Methods

Using the theory that individual fish of one species and age class that are collected on the same site will show variation in length around a mean length, fish of various age classes should show a normal distribution (a bell curve) when graphed. Thus when the entire population of a given species is plotted, there should be general clumpings of successive ages around successive given lengths. The entire population should show up, separated according to age classes.



The above assumptions are based on samples composed of large numbers of fish collected in a short period (a day or so) and made up of a good representation of all sizes and ages. Since collecting methods can exhibit selectivity and since there is a considerable amount of overlap in sizes of older fish, the length/frequency method requires additional information to make accurate decisions.

Aging Fish

2 years

3 years

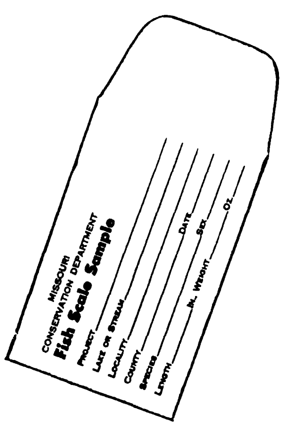
Most warm-blooded animals increases in size only until they reach maturity. Though maturity varies greatly with the species and to some extent the individual, mature body organs maintain themselves at a determined size and structure. Although fish do reach sexual maturity at a certain size or age, they continue to grow throughout their lifetime. While growth slows in old age, fish can add tissue throughout their lives.

As a fish grows, new tissue is added to its bony structures in a circular fashion (differential deposition) similar in appearance to the growth rings seen on a stump of a tree. Scales, like dermal bone, also show these seasonal changes in rate of growth. This is particularly true in waters that become cold enough to interrupt growth during the winter months.

Scales are shingling discs of bone with the exposed part covered by a very thin skin. Each scale is formed by the concentric layers of bone (circuli) which are laid down at the margin of the scale as the fish actively feeds and grows. During winter when the fish ceases to regularly feed, deposition of cell material slows and scale growth ceases or is retarded. The scale may even suffer some reabsorption at its margin. When active feeding resumes in spring, a distinct mark (annulus) is formed.

A fish can be aged by counting the annuli from almost any bony structure on or in its body. Thus the scales and bones of fish can tell a fisheries manager a great deal about the general health and well-being of a fish population. By measuring the distance between the various annuli and knowing the total length of the fish, a biologist can back-calculate and determine the fish's length at any given age.

Scale Method



Since scaled species make up the majority of fishes, the scale method is the most widely used in age and growth studies. During the collection of fishes, the biologist removes a few larger scales by gently scraping them from the mid-side of the fish just behind the gill cover (the fish will replace the scales in time). Scales from each fish are placed in specially designed envelopes that are marked with species name, total length (0.1 inch or nearest mm), weight (0.1 ounce or nearest gram), capture location and methods, time and date, collector's name(s), and pertinent comments.

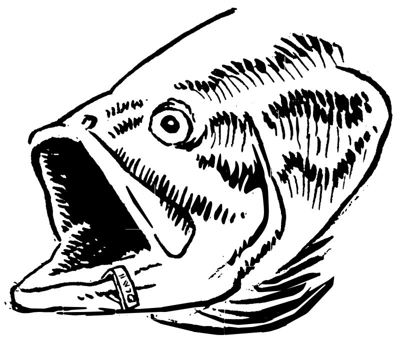
Determining age from the scales is often not as simple as it sounds. Seasonal cessation of growth due to a variety of factors (extreme heat, low water period of summer, or periodic pollution) may cause the formation of false annuli. Biologists use sophisticated methods involving expensive impression machines and projectors to aid them in making age determinations.

Other Aging Methods

Aging of non-scaled fish poses more difficulty for the biologist. A wafer-thin section of the catfish spine (usually pectoral fin) is cut with a jeweler's saw so that the concentric growth rings can be counted. A thin section of the fin ray of sturgeon

provides the same information. In order to age paddlefish, whose skeleton is largely cartilage, a portion of the lower jaw is sectioned. In much the same way, the otolith in the inner ear of the freshwater drum and the branchiostegal ray from below the gills of a gar are used for aging.

Fish Tagging



Since complete counts of fish populations are impractical, subsampling is necessary. Marking or tagging individual fishes enables the fisheries manager to determine the growth rate, movement, and harvest rate of select groups of fish. This information is then used as a basis for assessing the total population. For example, tagging studies have shown that the harvest rate of crappie in some Missouri reservoirs and small lakes is 40 to 70 percent, indicating a high utilization by anglers. Thus the importance of angler cooperation in returning tags from harvested fish cannot be overstated.

There is a variety of methods available for marking fish for future recognition. Fisheries managers in Missouri generally utilize the ones described below.

Fin Clip

The oldest, simplest, and most economical marking is the fin clip. A portion of soft fin rays, often the caudal fin, is clipped with scissors. While the procedure does not interfere with the mobility of the fish, no recognition of individual fishes is possible and regeneration of fins often obscures the mark. This method is best used for short-term studies.

Floy (Spaghetti) Tag

Composed of a small, brightly colored tubular tag that is injected into the musculature of the back posterior to the dorsal fin, the Floy tag contains a T-shaped end that lodges in the neural spines of the skeleton (the tag and injection gun resemble those used to apply plastic price tags to items of clothing). Because of possible trauma during penetration, the tag is usually not used with fish smaller than eight inches.

The Floy tag is usually imprinted with the identification of those doing the marking and the fish's own serialized number. Therefore, exact information can be obtained when the fish is recaptured or harvested.

Monel Tag

Appearing somewhat like a cross between a bird band and a hog ring, the Monel tag has been used to mark catfish in Missouri impoundments and sturgeon in the big rivers. It is usually applied to the lower jaw or operculum. (A tag attached to the jaw may interfere with feeding.)

Made of non-corrosive metal alloy, Monel tags have various information and identification numbers stamped on the flattened sides.

Radio and Ultrasonic Tags

The transmitter should not weigh more than 2% of the fish's body weight. Most tagged fish must weigh over 3 pounds.

The use of radio and ultrasonic telemetry is not a practical method for assessing fish populations, however, it is a valuable tool for charting the activity and movement of large fishes. In Missouri, it has been used in research studies of large impoundment and river species like paddlefish, blue and flathead catfishes, and hybrid striped bass.

While a telemetry study offers insight into the daily activities of a fish as its movements are followed by a directional receiver, it is difficult to assess all behaviors. A wildlife biologist can observe that a terrestrial animal moved to sleep, eat, mate, or complete a myriad of other life-sustaining activities. But a fisheries biologist may never directly observe his subject after it is tagged. Yet he can assume that the more time a fish spends in a location, the more needs are satisfied by the habitat. By knowing the habitat, he can use his knowledge to accurately predict what the fish is doing there. Discerning a species' need for space, food, cover, water quality, or migration, the biologist can better incorporate them into a management plan.

Other Marking Methods

Though not often used in Missouri, various other marking methods like cold branding and dye have been tried. Newer innovative micro-tags can be implanted in the cartilage of fishes too small for standard tags. As a small fish (perhaps bluegill) swims through sensors, numbers are monitored and recorded.

Population Estimates

Mark and Recapture

Through the use of mark-and-recapture data, approximate population numbers can be determined using one of several mathematical formulas. These formulas are based on the following assumptions:

1. Marked fish retain their identity marks
2. Marked fish are randomly distributed throughout the wild population
3. Marked fish are susceptible to the same degree of capture as the unmarked
4. Recruitment from growth or immigration has not increased fish numbers in the experiment
5. Losses through emigration and death occur in equal proportions among the marked and unmarked fishes.

If the above assumptions are not valid, adjustments must be made.

Mathematical Computations

Watkins Mill State Park Lake - 1980 (Estimation of population size of largemouth bass 7.0 inches and larger using Schnable Method)

Date	C	M	R	C_tM_t	$\Sigma(C_t M_t)$	ΣR
5-5	196	0	0	0	0	0
5-7	247	196	20	48,412	48,412	20
5-12	224	422	35	94,528	142,940	55
5-14	215	611	71	131,365	274,305	126
5-27	210	754	57	158,340	432,645	183
6-3	171	907	63	155,097	587,742	246

$$N = \frac{587{,}742}{246} = 2{,}389 \text{ LMB over 7''}$$

If a single recapture run is made, the Petersen Formula is used to estimate numbers:

$$\hat{N} = \frac{M(C)}{R}$$

$\hat{N}$ = population size at time of marking (single species in a closed system)

M = number of fish captured, marked, and released in the system

R = total number of marked fish recaptured in the population during a sample census

C = total number of fish observed or checked for presence of mark during sample census run

Although time consuming, multiple recapture runs will produce a more accurate estimate of population numbers. In this case, the Schnable Formula is most often used by Missouri Conservation Department fisheries biologists:

$$\hat{N} = \frac{\Sigma(C_tM_t)}{\Sigma R_t}$$

N = estimate of population size

C_t = total number of fish observed for presence of mark on day t

M_t = total number of fish marked at large on day t

R_t = number of marked fish that were recaptured during day t

Σ = the accumulative sum of

t (subscript) = at given day of capture

Creel Surveys

An appraisal of the success of management efforts to improve and maintain a fishery is dependent upon knowledge of previous and current harvests. The ability to predict future production also hinges on this knowledge. Thus records of fishing pressure and the degree of success are necessary.

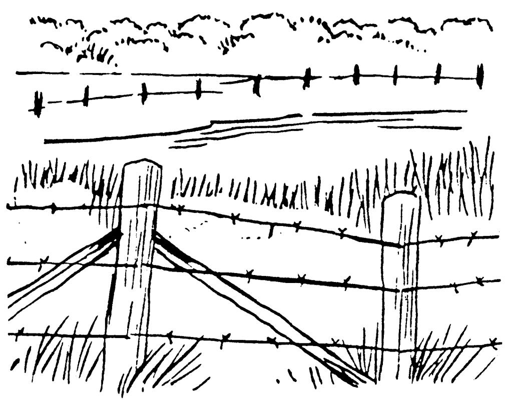
Creel census clerks interview anglers and record results of their fishing trips on special forms. They often ask to take scale samples or other biological data from the recorded harvests.

Analysis of creel census studies gives information on the seasonal or annual catch in species, numbers, sizes and weights; fishing pressure; and harvest per unit of effort (i.e. fish/hour or fish/trip). In addition, such data often indicates characteristics of local fishermen, such as their residence, sex, skill levels, preference for species, and types of gear used, as well as the costs and returns of sport fishing. The seasonal and spatial distribution of fishes, and the effects weather has on their distribution and behavior can also be determined. Such surveys can be used to determine the recreational and economic values of various fish species. After reviewing all the data, the manager must determine if the fishery is producing up to its potential and if fishermen enjoy it.

Management Practices

Once the aquatic systems are surveyed and data is accumulated and analyzed, fisheries management has just begun. Using the research data, biologists must develop a management plan for each system, focusing on those species considered most desirable and those requiring attention. Then through tedious and dedicated labor, combined with constant monitoring, they must put the plan into action.

Watershed



A stream, pond, or lake is not an isolated vacuum. Each can only be as healthy as the watershed that surrounds it. The first step in developing or improving fish populations must often be a well designed and implemented management plan for the watershed. While water quality may be improved on the short-run with stop-gap measures, long-term improvement depends on the maintenance of a quality flow into the system.

The larger the watershed is, the less control the manager has over it. On small impoundments, it may be feasible to place the entire drainage in permanent grass cover to reduce erosion and the resultant siltation. But on river systems, the manager may only be able to control devastating pollution such as chemical dumping by industry or sewage effluent of municipalities. The major concern is that what flows into the system, especially closed ones like impoundments, is going to stay.

Today Missouri Conservation Department fisheries managers work with landowners in before-the-fact watershed planning of ponds and small lakes. With pre-construction designing, impoundments can be built to provide optimal fish production (See *Missouri Pond Handbook* (Dillard, 1981)).

Besides working to reduce and prevent the degradation of water quality in streams, managers also recognize the negative effects of stream channelization. Channelization removes the natural diversity of pools and riffles, destroys protective cover, and shortens the length of the stream.

Cover

Often called shelter or structure, aquatic cover is usually rootwads, stickups, submerged tree branches, growing vegetation, and rock. Cover, other than aquatic plants, is rarely too abundant in natural waters. Besides increasing the substratum for fish food production, cover offers escape for young developing fish fry, shade, and spawning sites. As anglers know, cover often concentrates fishes of catchable size where they rest, feed, or escape from larger predators.

In waters lacking natural cover, artificial fish attractors can be substituted. Brush piles of decay-resistant cedar or hardwoods can be tied, weighted, and sunk in lake coves or similar waters. Old auto tires, while lacking aesthetic appeal, can also be used (see Neuswanger, 1983). Catfish exhibit a preference for tiles or larger pipes during their annual spawning season in the spring.

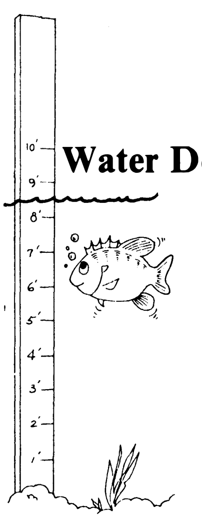
Vegetation

Submergent and emergent aquatic plants of all varieties serve as areas of fish food production and shade. Yet extensive growths may result in excessive decomposition which may remove the dissolved oxygen from the water when it is needed by fish during critical periods (seasonal anaerobiosis). Some floating plants like blue-green algae even produce toxins during a bloom. Mats of vegetation also decrease the amount of open water available to anglers. Plant growth problems are usually more evident in shallow waters of high fertility.

As a rule of thumb, most fishing ponds should be maintained with vegetation occupying about 20 percent of the surface area. Control of overabundant growths usually involves chemical, mechanical, or biological methods. Each has specific benefits and drawbacks (See Aquatic Plant Management in Missouri, Belusz, 1984).

Food For Fishes

Food is never too abundant in an aquatic system. Though seldom ever prescribed since it can precipitate other problems (like seasonal anaerobiosis), fertilization increases plant growth, providing more zooplankton and insect foods. Under certain circumstances game fish foods such as minnows may be introduced and managed if suitable spawning and escape cover exists. In some cutltured fisheries, high populations are systematically fed prepared foods (catfish farming).



Water Depth and Level

In order to assure survival of fishes through winter, especially in north Missouri, most impoundments should have a minimum depth of around 8 feet. The ability to raise or lower water levels can be an effective tool in managing vegetation growths and spawning success. Generally, water level fluctuations should remain stable or should increase to benefit fish spawning. Raising the water level into edge vegetation may provide more pond edge escape cover for young fry. Falling water levels could leave many nests "high and dry." When the dams of large reservoirs block the flow of streams, provisions are often made to allow a minimum flow that will insure fish survival.

Siltation and Other Pollution

Perhaps the most widespread pollutant of Missouri lakes and streams results from erosion of soils, especially in the farm country of northern Missouri. The resultant water turbidity is detrimental to fish and invertebrate populations.

Siltation, resulting from the settling of soil particles, is the agent of ecological succession of impoundments, causing an aging (shallowing) of such waters. Ideally, watersheds should be managed with soil conservation practices, and impoundments and streams shores should be stabilized with plantings of soil-binding shrubs or trees. The dams and steep banks of larger lakes may be riprapped to prevent erosion from wave action.

Other methods of clearing impoundment waters for temporary relief are available (see *Missouri Pond Handbook* (Dillard, 1981)). Some fishes such as carp and bullheads that are rooting bottom-feeders, disturb the system's substrate and keep the waters in constant cloudiness. If such problems persist, total renovation of the fish population is necessary.

Various other pollutants contaminate Missouri waters. Streams, ponds, and lakes have often been purposely used as natural sewers and cesspools, receiving everything from deadly dioxin to pathogenic organisms such as raw sewage, heavy metals as industrial effluent, and agricultural pesticide run-off. Substances toxic to fishes and people—where the water is used for human recreation and consumption—should be excluded.

Interspecies Relationships

Certain combinations of fish species produce more fishing of a desired quality than other species combinations. While the introduction of bluegill, largemouth bass, and channel catfish to Missouri ponds is a tried-and-tested effective combination, fisheries managers are careful to identify available unused niches and interspecies relationships before introducing new species to the system. Exotics, such as the carp, usually lack natural population controls and are seldom desirable. Exceptions to this rule in specified waters are trout and muskellunge.

A body of water can only support a certain amount (biomass) of fishes at each level of the food chain. If fish numbers are excessive the fish will be of smaller size than if there were fewer of each species. Overpopulated species can be assisted by properly tailored fishing regulations, adding effective natural predation, or occasionally by selective mechanical or chemical removal.

Non-game species often compete directly with preferred game fish for food, cover, and space. If a large biomass of non-game fishes is present in a system, the total biomass of predacious game fishes present at the same time is likely to be smaller than optimal.

Fishing Regulations

An impoundment should be considered as an aquatic farm with gamefish as the desired crop, raised with management of fertilizer and seed, resulting in harvest.

More and more Missouri fishermen are putting an ever increasing demand on the fishery resources of the state. Because of this demand, unrestricted harvest of most sport fishes cannot be allowed. Fishing pressure may be too great, too small, or too species selective to permit optimal harvesting of the fish crop.

Sometimes it is practical to manage a group of aquatic systems, particularly open systems like streams, with general statewide fishing regulations. On the other hand, public impoundments usually require a more individualized approach. The result of inadequate harvest regulations is often exhibited by the stockpiling of less desirable species or sizes of fish, or by the overpopulation and slowed growth of desirable game fishes. It is important to note that fishing regulations can maintain present conditions or change the unfavorable to the more acceptable, but they can not always offset environmental problems that are beyond the managers' control.

Length Limits

Length limits as fishing regulations are usually set to protect certain easily measurable sizes of fish of a given species from harvest.

Minimum Length Limits

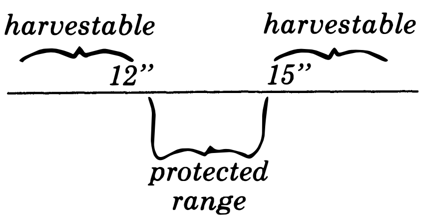
Minimum length limits are often set on certain game fish (trout, black bass, walleye, and crappie) to assist in maintaining a size distribution that can take advantage of a wide variety of food. For example, larger bass eat larger food (a 12-inch largemouth bass can consume a four- or five-inch bluegill) and may not have to compete with smaller bass for smaller prey. Thus the entire system is benefited.

Minimum length limits are sometimes set so that the species are protected from harvest until they have had time to mature and spawn. This is particularly true for late-maturing species like sturgeons. For the few species (i.e., muskellunge and musky-pike hybrids) incapable of spawning in Missouri waters due to genetics or environmental preferences, arbitrary minimum length limits are set to maintain the trophy fisheries.

Slot Length Limits

Largemouth Bass

State Impoundments



In some instances, angling pressure can be manipulated to benefit the fishery, particularly if a size selective harvest is needed. The slot length limit has become more frequently used as a management tool in recent years with largemouth bass on Missouri fishing lakes. While the protected zone varies as to species and impoundments, bass between 12 and 15 inches are most often protected from harvest. The angler may harvest the more numerous smaller fish and larger trophy fish, but he must release the mid-range bass to provide adequate predator control on bluegill. This results in maximum utilization of prey, while allowing many more bass to quickly reach the 15-inch catching range.

Creel Limits

The numerical daily creel limit is a widely accepted method of "limiting" the catch and distributing the harvest among anglers of individual fish species on a daily or possession basis. Yet, it usually has little overall effect on harvest. To effectively limit harvest, creel limits might have to be reduced to one or two fish per species each angler trip. This might be generally unacceptable to most anglers.

Unfortunately, a creel limit is often looked upon as a goal for the angler to reach. Many fishermen focus on the creel and forget the real reason why they are fishing. Reducing creel limits may have some psychological value in pointing out the scarcity of the resource, but it does not directly limit overharvest of the fishery since it does not restrict the number of anglers, nor the length of fishing trips.

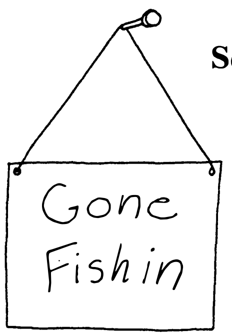
Quota Limits

Although not practical in any but the most severe cases, the quota limit would ideally be the best method of managing fish harvest. The fisheries manager would set a predetermined harvest on the impoundment for each species. When that number is

reached, the area is closed to fishing for that particular species. Variations such as creating refuge areas or "no fishing zones" have also been tried. Generally, fish are too mobile, rendering the refuge idea ineffective.

Methods of Harvest

Missouri regulates types of fishing gear, bait, and other apparatus that anglers may use to harvest fish. The regulations vary according to the species of fish and the waters from which they are caught. An attempt is made to allow an optimal, ethical harvest by a majority of the State's citizens without harming the fisheries resource. Consequently, in heavily fished state lakes, only three rods and reels are allowed per person.



Seasons

Legal angling seasons are set by the Missouri Conservation Commission to allow optimal use of the fish resource of the state without causing that resource undue damage. During critical periods, such as spawning season when fish are particularly vulnerable and a majority are likely to be taken by only a small number of anglers, seasons may be closed. Thus, the legal season is timed to avoid such periods while maximizing use for the greatest number of sport fishermen.

Education and Public Relations

The effectiveness of fisheries management regulations hinges almost totally upon their acceptance by Missourians. Fisheries managers and the Conservation Department must continually carry on viable education and information programs so that citizens will understand the basic resource problems and resultant management decisions. Through constant use of youth and adult education programs, magazines, news releases, electronic media, and public meetings, an informed public supportive of valid regulation changes can be maintained.

Education is a two-edged sword. It has often been noted that a good sport fisheries manager is even better if he is also a fisherman. Managers can better understand the fundamental public relations problems of anglers if they, too, comprehend the concerns and jargon of the sport. Otherwise, the referral of angler concerns would be likened to "describing a rainbow to a blind man." The biologist might understand the words but not truly comprehend the meaning.

Summary

Fishing is a very important activity in Missouri's ponds, lakes, and streams. An ever increasing number of fishermen expect a nondiminishing supply of desirable game fishes from the waters of the state. Since aquatic systems are often used as sources of clean water, recreation, and even hydroelectric power, game fish production is often not a major priority. Other societal pressures—irrigation, navigation, sewage dumping and pollution, channelization and watershed development—may often vie as priorities at the expense of optimal fisheries.

Fisheries management attempts to "manage" each aquatic system to provide optimal sustained yields of desirable species and sizes of game fishes for the maximum prolonged usage by the citizens of the state. Yet, each system is a separate entity with its own peculiar set of interacting biological, chemical, and physical characteristics. In addition, each is also a constantly changing, dynamic aquatic system. Using a vast reservoir of knowledge, training, experience, and equipment, fisheries managers must study each aquatic system and implement flexible and responsive management plans suitable for the particular stream, pond, or lake...and acceptable to the citizens of the state. Missouri fishing depends on it!

The following lesson plans have been developed to aid the instructor in classroom presentation of the information contained in the instructional unit. References are made to specific aquatic investigative activities which will add practical understanding of fisheries management in Missouri. These activities can be found in Aquatic Field And Classroom Activities, a supplement to conservation education programs of the Missouri Department of Conservation.

Lesson Plan No. 1

Title: Introduction to Fisheries Management

Materials: Transparencies of Energy Flow Through an Aquatic System (Appendix 1) and Factors Affecting Fishery Management (Appendix 2); overhead projector; film: "Downstream" (MDC Film Loan); 16mm projector and screen.

Objectives: After completing the lesson, the students should be able to:
1. Define a fish and list two reasons why it is important to people.
2. Describe four unique characteristics of water.
3. Describe three levels of energy transfer that take place in an aquatic system.
4. Describe how societal pressures affect fishery management.
5. List the scientific disciplines in which a fishery manager must have specific training.

Method: Lecture, discussion, film

Procedure:

I. Introduction
   A. Fish have considerable social and economic value
      1. Fish rank high as a source of food for humans
      2. Fishing is a major participatory sport in Missouri and the United States
   B. Fisheries management is important in maintaining populations of desirable fish

II. Presentation
   A. Fish are cold-blooded animals with backbones, gills, and fins
   B. Fish are dependent upon water
      1. Water has unique characteristics
         a. Exists as a solid, liquid, or gas
         b. Becomes less dense than liquid water when it freezes
         c. Has a dissolving power greater than any other liquid
         d. Acts as a buffer against extreme temperature changes
      2. Energy is transferred in water
         a. Light energy is transferred from the sun to producer organisms
         b. Producer organisms provide food for consumer levels through photosynthesis
         c. Energy is transferred from animal to animal as each is consumed by another
   C. Fisheries managers must look at each aquatic system individually
      1. Natural environmental factors vary in each system
         a. Chemical characteristics
         b. Physical characteristics
         c. Biological characteristics
      2. Aquatic communities constantly change and evolve through ecological succession

3. Societal pressures affect fishery management
   a. Recreation and navigation
   b. Hydroelectric power and water storage
   c. Irrigation and channelization
   d. Watershed land use
   e. Acid rain and sewage effluent

D. The fisheries manager is alien to the aquatic environment
E. Fisheries managers must have training in and a working knowledge of many scientific fields

III. Summary
   A. Have students compare three fishing areas such as a river, a community lake, and a resort area, and discuss how environmental factors and societal pressures vary in each.
   B. Film: "Downstream"

Lesson Plan No. 2

Title: Living Organisms in an Aquatic System

Materials: Transparency of Sampling Aquatic Organisms (Appendix 3); overhead projector. For additional materials refer to "Habitats of the Pond and Small Stream and Their Living Inhabitants," Activity 1 in *Aquatic Field and Classroom Activities.*

Objectives: After completing the lesson, the students should be able to:
1. List three food sources for a fish population.
2. Describe the methods used to sample plankton, bottom organisms, and aquatic vegetation.
3. List three reasons why aquatic vegetation is important in an aquatic system.
4. Describe four methods of sampling fish populations.

Method: Lecture, discussion, field study (Activity 1: "Habitats of the Pond and Small Stream and Their Living Inhabitants")

Procedure:

I. Introduction
   A. In order to effectively manage an aquatic system fisheries biologists assess the presence and condition of living organisms in that system

II. Presentation
   A. Plankton is a major source of food for almost all species of fish at some point of their lives
      1. Plankton nets are used to take plankton samples
   B. Bottom organisms serve a variety of purposes in an aquatic system
      1. The presence or absence of bottom organisms is a key water quality indicator
      2. The number of bottom dwellers is used as an index of available fish food

3. Special dredges are used to take bottom samples

C. Aquatic vegetation has several functions in an aquatic system
   1. Aquatic vegetation is at the base of the fish food chain
   2. Vegetation provides shelter for small fishes
   3. Aquatic plants stabilize shorelines and provides shade, protection, and concealment
   4. Plant hooks and rakes are used to collect samples of aquatic vegetation

D. The fisheries manager uses a variety of methods to sample a complete cross section of existing fish populations
   1. Electrofishing
   2. Nets
      a. Gill nets
      b. Trap nets
      c. Meter nets
      d. Seines
   3. Observation
   4. Chemical methods

III. Summary

A. Fisheries managers use data collected on aquatic organisms to determine the condition of the aquatic system

B. Fisheries managers will develop and implement plans to improve the condition of an aquatic system

C. Field study; refer to Activity 1: "Habitats of the Pond and Small Stream and Their Living Inhabitants"

Lesson Plan No. 3

Title: Assessing Water Quality

Materials: Transparency of Tolerance of Fish to Temperature Fluctuations (Appendix 4); overhead projector. For additional materials, refer to "Physical and Chemical Properties of the Water of a Pond or Small Stream," Activity 2 in *Aquatic Field and Classroom Activities.*

Objectives: After completing the lesson, the students should be able to:
1. List four chemical factors in an aquatic system that affect fish and plant life.
2. Define anaerobiosis and supersaturation and tell how each relates to water quality.
3. List the physical characteristics of an aquatic system that affect fish and plant life.
4. Describe how water temperature and turbidity affect water quality.

Method: Lecture, discussion, field study (Activity 2: "Physical and Chemical Properties of the Water of a Pond or Small Stream")

Procedure: I. Introduction

A. Chemical and physical analyses of water reveal an aquatic system's potential to support aquatic life

B. All physical and chemical factors interact to affect water quality

II. Presentation

A. The absence or excess of chemicals in water is important in determining the productivity of an aquatic system

1. Fish need oxygen to breathe
   a. Oxygen levels fluctuate daily and seasonally
   b. Seasonal anaerobiosis is the complete depletion of dissolved oxygen in an aquatic system
   c. Supersaturation is too much dissolved oxygen in an aquatic system
2. Carbon dioxide is produced by the respiration of plants, animals, and decomposer bacteria
3. The pH level of water indicates the presence or absence of pollution
4. The fertility level of the system determines the amount of plant growth

B. Physical characteristics of an aquatic system determine its ability to sustain fish populations

1. Water temperature is directly influenced by the air above it
   a. Chemical factors rely on water temperature
   b. Fishes are grouped according to their tolerance to temperature fluctuations
2. Turbidity is caused by organic and inorganic agents suspended in water
   a. Turbidity reduces photosynthesis and lowers overall productivity
3. Water color may have the same effect as turbidity

III. Summary

A. Field study; refer to Activity 2: "Physical and Chemical Properties of the Water of a Pond or Small Stream"

Lesson Plan No. 4

Title: Assessing Fish Populations

Materials: Transparency of Aging Fish: Scale Method (Appendix 5); overhead projector. For additional materials, refer to "Estimating Fish Populations" and "Fish Populations of a Pond," Activities 3 and 4 in *Aquatic Field and Classroom Activities.*

Objectives: After completing the lesson, the students should be able to:
1. Tell the major goal of fisheries management.
2. Describe the scale method of aging fish.
3. Describe two methods of marking fish.

Method: Lecture, discussion, field study (Activity 3: "Estimating Fish Populations" and Activity 4: "Fish Populations of a Pond")

Procedure:

I. Introduction
   A. The major goal of fisheries management is to maintain an optimum sustained yield of desirable fishes.
   B. The fisheries manager must determine the growth rate, age and size composition, densities, recruitment, and mortality of the fishes in a system

II. Presentation
   A. Knowledge of the age and growth rate of a fish is useful in management
      1. Known age method
      2. Length-frequency method
      3. Aging fish
         a. Scale method
         b. Other methods
   B. Fish tagging enables the fisheries manager to determine the growth rate, movement, and harvest rate of groups of fish
      1. Fin clip
      2. Floy tag
      3. Monel tag
      4. Radio and ultrasonic tags
   C. Approximate population numbers can be determined through the use of mark-and-recapture data
      1. Mathematical computations
         a. Petersen Formula
         b. Schnable Formula
      2. Creel surveys

III. Summary
   A. Fisheries managers will analyze all the data collected on fish populations to determine if the fishery is producing up to its potential
   B. Fisheries managers will develop and implement management techniques to improve the fish population
   C. Field study; refer to Activity 3: "Estimating Fish Populations"
   D. Field study; refer to Activity 4: "Fish Populations of a Pond"

Lesson Plan No. 5

Title: Fisheries Management Practices

Materials: Transparency of Factors Affecting Water Quality (Appendix 6); overhead projector. For additional materials, refer to "Determining the Watershed: A Map Reading Exercise," Activity 5 in *Aquatic Field and Classroom Activities.*

Objectives: After completing the lesson, the students should be able to:

1. List the factors that can be manipulated in order to improve the quality of an aquatic system.
2. Describe three functions of aquatic cover.
3. Tell how soil conservation practices can improve water quality.
4. Discuss five types of fishing regulations that help to control fish populations and sizes.
5. Tell why education and public relations are important to fishery management.

Method: Lecture, discussion, field study (Activity 5: "Determining the Watershed: A Map Reading Exercise")

Procedure:

I. Introduction
   - A. Collecting and analyzing data from aquatic systems is just the first step in fisheries management
   - B. Fisheries managers develop a different management plan for each individual aquatic system

II. Presentation
   - A. Fisheries managers may manipulate or regulate many factors to improve the quality of an aquatic system
     1. Watershed—the aquatic system is only as healthy as the watershed that surrounds it
     2. Aquatic cover
        - a. Fish food production
        - b. Shelter and escape
        - c. Spawning sites
     3. Vegetation serves as area of fish food production
     4. Food is never too abundant in an aquatic system
        - a. Fertilization
        - b. Minnows
        - c. Prepared foods
     5. Water depth and level
        - a. Affects vegetation growths
        - b. Affects spawning success
     6. Siltation and pollution
        - a. Soil conservation practices
        - b. Management of toxic substances

B. Management of certain combinations of fish species produces more fishing of a desired quality
C. Fish populations and sizes are controlled by fishing regulations
   1. Length limits
      a. Minimum length limits
      b. Slot length limits
   2. Creel limits
   3. Quota limits
   4. Harvest methods
   5. Fishing seasons
D. Education and public relations result in an informed public supportive of management decisions

III. Summary
   A. Fisheries managers use knowledge, training, experience, and equipment to study each aquatic system and implement management plans suited to it
   B. Field study; refer to Activity 5: "Determining the Watershed: A Map Reading Exercise"

Glossary

acid: Any substance that yields to its solution or other substances hydrogen ions; a compound that can react with a base to form a salt. Of a pH less than 7.

acid rain: Atmospheric precipitation that is composed of the hydrolized by-products from oxidized halogen, nitrogen, and sulfur substances.

alkaline: That which forms with an acid to form a salt and has a pH above 7; opposite of an acid.

anaerobiosis: The complete dissolved oxygen depletion of an aquatic system that results in catastrophic fish mortality, usually occurring seasonally as summer kill or winter kill; flash mortalities resulting from sudden, temporary spread of oxygen deficient waters at the time of spring or fall overturn. (See summer kill, winter kill, eutrophication, and overturn.)

annuli: The distinct mark formed when growth of fishes resumes and circuli are added to the scales, usually in the spring after winter slows growth and causes resorption of the outer margin of the scale bone; used to age scale fish as growth rings.

aquatic: Growing or living in or upon water; done in or upon the water; of or pertaining to water.

attrition: The loss of the fish in a population in the normal course of events.

bacteria: Any of many single-celled microorganisms (Class Schizomycetes) that occur in a wide variety of forms and have a wide range of biochemical properties. Some are aerobic, some facultative (capable of living under different environmental conditions). Many bacteria are pathogenic, but many are vital to such ecological processes as decomposition.

benthic (region): The bottom of a body of water.

benthos: The plant and animal life whose habitat is the bottom of a sea, lake, or river.

biomass: The amount of living matter in a given unit of the environment.

carbon dioxide: A colorless, odorless, nonpoisonous gas (CO_2), produced during microbial decomposition and animal respiration, that forms carbonic acid when dissolved in water.

carrying capacity: The maximum population that a given ecosystem can support for an indefinite period of time.

channelization: The alteration of the flow characteristics of a stream channel by cleaning, excavating, realignment, lining, or other means in order to increase its capacity.

circuli: The concentric layers of bone layed down at the margin of the scale as the fish grows.

cold-blooded animals: Animals having a body temperature that fluctuates, approximately that of the surrounding air, land, or water; same as poikilothermic (e.g. fishes and reptiles).

community: An aggregation of organisms, plants and animals, within a specified area.

consumer: An organism that lives off other organisms. Consumers are often designated as primary consumers (herbivores), secondary consumers (carnivorous), and micro-consumers (decomposers).

cover: Vegetation or other material used by wild animals, including fish, for nesting, rearing of young, resting, escape from predators, or protection.

creel census: A canvass of anglers to gather data on their catches, time spent fishing, etc.

dissolved oxygen: The amount of gaseous oxygen (O) dissolved in a liquid, usually water.

diurnal: Pertaining to animals that are active during daylight.

dorsal fin: A median or un-paired fin that arises and extends along the middle of the fish's back and may be divided into several parts, the anterior often being spiny.

ecological pyramids: The interaction of the food chain phenomena showing energy losses at each transfer graphically illustrated by drawing the base or producer level with successive consumer levels added as tiers. They may be of three types: 1. the pyramid of numbers in which the numbers of individual organisms at each level is depicted, 2. the pyramid of biomass based on the dry weight caloric value or other measure of the total amount of living material, and 3. the pyramid of energy in which the rate of energy from successive levels is shown.

ecology: The study of interrelationships of organisms to one another and their non-living environment.

ecosystem: A contraction for "ecological system;" the interacting system of a biological community and its non-living environment.

effluent: Solid, liquid, or gaseous wastes that enter the environment as by-products of man-oriented processes.

electronarcosis: A condition of temporary unconsciousness and paralysis in fishes, caused by passing an electric current through water, during population sampling by electrofishing.

emergent vegetation: Plants that grow rooted to the bottom of an aquatic system whose leaves and usually stems emerge or extend above the surface (e.g. cattails and arrowheads).

erosion: The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.

eutrophication: The aging process of lakes whereby aquatic plants are abundant and waters are deficient in DO. The process is usually accelerated by enrichment of water with surface run-off containing nitrogen and phosphorus.

exotic: An organism or species that is not native to the region in which it is found.

fecundity: The birth rate potential of a fish population; the potential to give birth. Survival is a different matter and is important in considering recruitment. (See recruitment)

fertility: The quality, state, or degree of having the enrichment necessary to produce and support plant growth.

fishery: The place of or the specific type of fish resource available to fishermen (e.g. warm-water fishery, bass fishery, pond fishery).

floating vegetation: Aquatic plants whose roots arise in the water and whose stems and leaves are found floating in or on the water (e.g. duckweed).

food chain: The sequence of transfers of energy in the form of food from organisms in one trophic level to those in another.

galvanotaxis: A forced response from an external stimulus that causes most fish to swim toward the positive electrode of a mild direct current (DC) field; often used in electrofishing to sample fish populations.

gas bubble disease: Fish in deeper colder waters, especially below the spillways of large dams, where gas is held in solution under pressure, take super-saturated air into their blood and as they swim into shallow, warmer waters, the pressure lessens and the dissolved oxygen comes out of solution in the fish's circulatory system and tissues, often leading to death.

game fish: A fish sought after for its flesh, trophy, or sporting value, and which is considered to possess those sporting values that enhance the angling experience. (In Missouri, consult the *Wildlife Code.*)

habitat: The environment in which the life-needs of an organism, populations, or community are supplied; comprised of water, food, cover, and space.

harvest: The gathering or taking of a crop of any kind; that portion of gross production which exceeds the amount or number needed for reproduction during the subsequent production period, thus the surplus is available for consumption.

heat of fusion: The quantity of heat that must be supplied to change a unit mass of a substance from the solid to the liquid state at constant temperature. (For water the heat of fusion, or the amount it takes to change 0° C ice to 0° C liquid is 80 calories per gram.)

heat of vaporization: The quantity of heat that must be applied to change a unit mass of a substance from the liquid to gaseous (evaporation) state at constant temperature (for water the heat of vaporization, or the amount of energy it takes to change 100° C liquid water to 100° C steam is 540 calories per gram.)

impoundment: Generally, an artificial collection or storage of water, as a reservoir, pit, dugout, or sump. (See reservoir)

invertebrate: Animals without an internal skeletal structure (e.g. insects, mollusks, and crayfish).

lake: An inland body of standing water, usually thought of as being of considerable size; to the limnologist, a lake is a generally larger body of water that has depths at which light does not penetrate to the bottom.

mortality: Deaths as a component of population change.

neural spines: In bony fishes, the row of "dorsal ribs" that extend from each vertebra intramuscularly in a single plane along the fishes' backs.

nocturnal: Pertaining to those animals that are active during darkness.

non-game fish: Those species of fish not prized for game purposes; most are more tolerant of changing environmental conditions than are game species.

operculum: The bony gill cover of fishes.

organism: Any living thing.

otolith: The "earstone" found in the inner ear of bony fishes that enlarge by addition of concentric layering of bone as the fish grows; sectioned and used in age assessment studies of fishes like the freshwater drum.

overturn: The period of mixing (turnover), by top to bottom circulation, of previously stratified water masses.

oxbow lake: A generally crescent-shaped lake which was formed by a stream meander being cut-off from the main stream.

pathogenic organism: An organism, usually bacteria, fungi, viruses, and protozoa, capable of producing disease.

pectoral fins: The anterior pair of fins of fishes, corresponding to the arms of people, located laterally on the shoulder girdle just back of the operculum.

pelagic: The region of open sea or large lake away from the shore without submergent vegetation.

pH: A numerical measure of acidity or hydrogen ion activity; a pH value of 7.0 is neutral, pH values below 7.0 are acid, and pH values above 7.0 are alkaline.

photoperiod: The length of daylight hours in a 24-hour day, lengthening or shortening according to the season.

photosynthesis: The manufacture by plants of carbohydrates and oxygen from carbon dioxide and water in the presence of chorophyll, using sunlight as an energy source.

plankton: Those suspended, floating, or weakly swimming minute plants and animals in the water that provide a base for the aquatic food chain; divided into phytoplankton (plants) and zooplankton (animals).

pollution: The condition caused by the presence in the environment of substances of such character, and in such quantities, that the environment is impaired or rendered offensive for life.

pond: A natural or man-made depression, smaller than a lake, filled with water; to the limologist, a pond is a generally smaller body of water so shallow that light penetrates to the bottom throughout its depth.

population: A group of organisms of the same kind.

predator: An animal that lives by capturing and devouring other animals.

prey: The animal that is or may be seized by another for food.

producer: An organism that can use radiant energy to synthesize organic substances from inorganic materials; generally a green plant.

recruitment: The addition of the fish in a population naturally by natality or migration or artifically by stocking.

reservoir: Any natural or artificial holding area used to store, regulate, or control water.

respiration: The complex series of chemical and physical reactions in all living organisms by which the energy and nutrients in foods are made available for use. Respiration and breathing are not the same; respiration is the exchange of oxygen and carbon dioxide in the cells and breathing implies the use of lungs to bring oxygen in and expel carbon dioxide from the body.

rough fish: See non-game fish.

saturation level: (of water) The point at which water of a given temperature at a given pressure will no longer absorb a gas into itself.

scales: The thin shingling disks of bone, with the exposed parts covered by a very thin skin, that cover most of the body of scaled fish. Of a variety of types, most modern scaled fish have cycloid or ctenoid scales that add concentric layers of bone (circuli and annuli) as the fish grows.

schooling: The tendency for certain species of fishes to move together in a group, equally spaced apart in all dimensions, to carry out life-sustaining functions such as feeding, reproduction, and protection during movement.

silt: A soil separate consisting of particles between 0.05 and 0.002 millimeters in equivalent diameter. When eroding from the watershed, it often suspends in water, creating increased turbidity.

space: An expanse extending in three dimensions in an aquatic system, with varying distances or spacing out required for life-sustaining activities of fishes (reproduction, food-getting, and protection), varying according to species, size and age, and activity.

standing stock: The total biomass of an area at a given time; the quantity of a given species at a given time.

stratification: The condition of a body of water in which the successive horizontal layers have different temperatures, each layer more or less sharply differentiated with adjacent ones.

stream: As flowing-water ecosystems, streams are incomplete and get their water from springs or watershed drainage; they vary in size and composition according to the area (size of flow, soil type, nutrient load, effluents, etc.) that they drain (e.g. creek, spring, brook, river).

structure: Fisheries and sportfishing jargon referring to the cover of an aquatic system that would provide shelter for fish (e.g. vegetation, rootwads, treetop stickups, rocks, rock ledges, and the like).

stunting: The substantial lag in rate of growth of a population in comparison to the average of similar systems in a region.

submergent vegetation: Plants that grow rooted to the bottom of an aquatic system whose leaves generally remain submerged, although a few may be floating (e.g. pondweed, coontail, and Elodea).

substrate (same as substratum): The ground or other solid on which an animal moves or plants are rooted (e.g. the bottom of an aquatic system).

succession: (ecology) The progressive development of vegetation toward its highest ecological expression, the climax; the replacement of one plant community by another.

summer kill: A complete or partial kill of a fish population in ponds or lakes during the warm months; variously produced by excessively warm water, by a depletion of dissolved oxygen, by the release of toxic substances from a decaying algal bloom, or by a combination of these factors. (See winter kill.)

supersaturation: A condition in which a solution has more solute, often gas, dissolved than is normally possible under existing conditions.

sustained yield: A condition in which the rate of utilization or consumption of a resource such as a fish population does not exceed the rate of recovery or production.

synergy: The simultaneous actions of two or more substances that together have a greater total effect than the sum of their individual effects.

telemetry: Any device for measuring physical phenomena (e.g. fish location and activity) at some remote point and transmitting, especially by radio, the values obtained to a distant observer or recorder.

terrestrial: Consisting of land as distinguished from water, living on land rather than in water, in the air, in trees, etc.

thermal stratification: See stratification.

turbidity: The cloudy condition caused by suspended solids in a liquid.

vertebrates: Animals that have an internal skeletal system (e.g. fish, reptiles, amphibians, birds, and mammals).

warmblooded animals: Animals having a body temperature that remains relatively constant, independent of and usually higher than that of the environment; same as homeothermic (e.g. mammals and birds).

watershed: The land area that drains toward a natural surface water system (more precisely, a given point on such a system).

winter kill: The death of fish in a body of water during a prolonged period of ice and snow cover; deaths are caused by oxygen exhaustion due to respiration and lack of photosynthesis.

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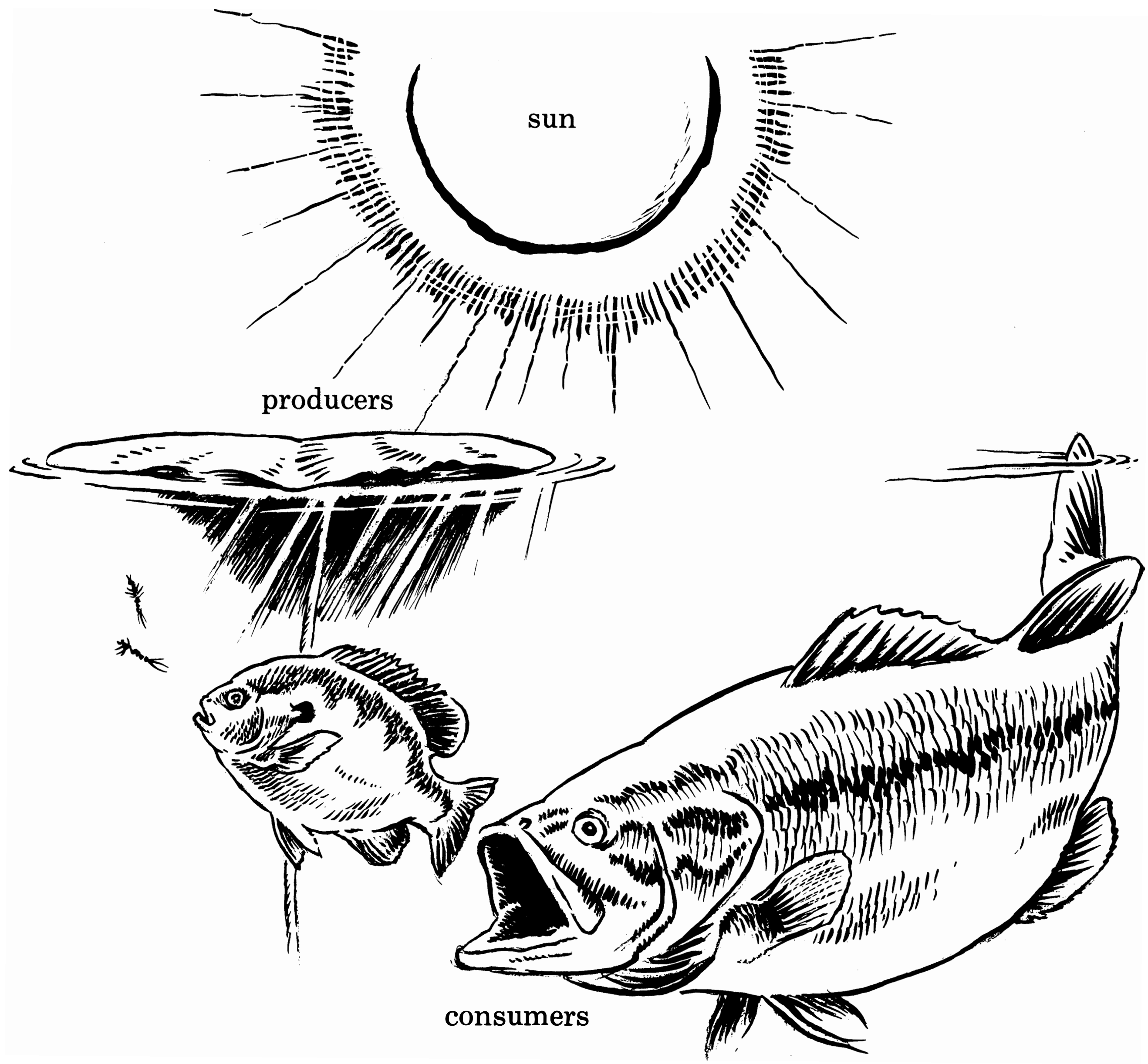
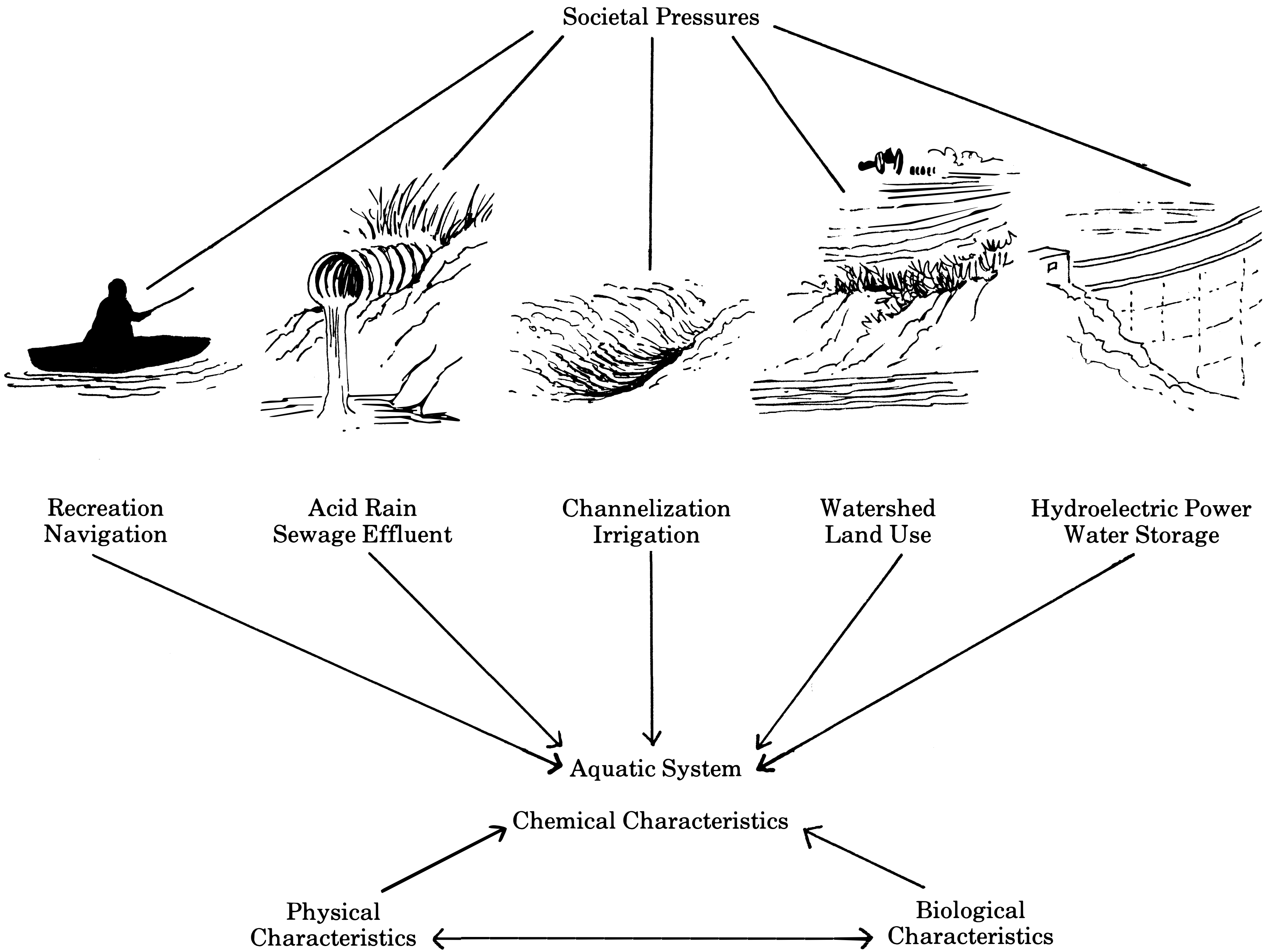
Appendix 1—Transparency

Energy Flow In An Aquatic System

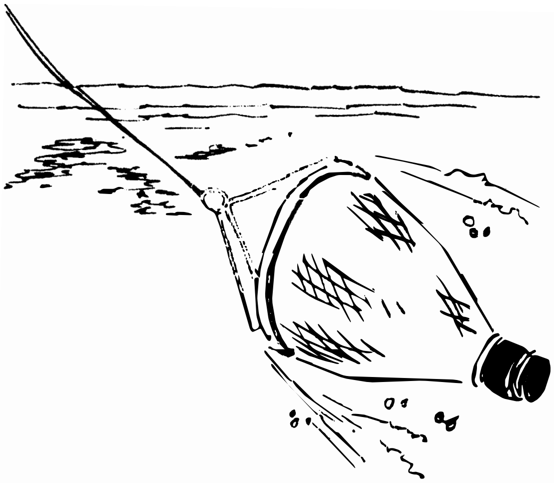


Factors Affecting Fishery Management

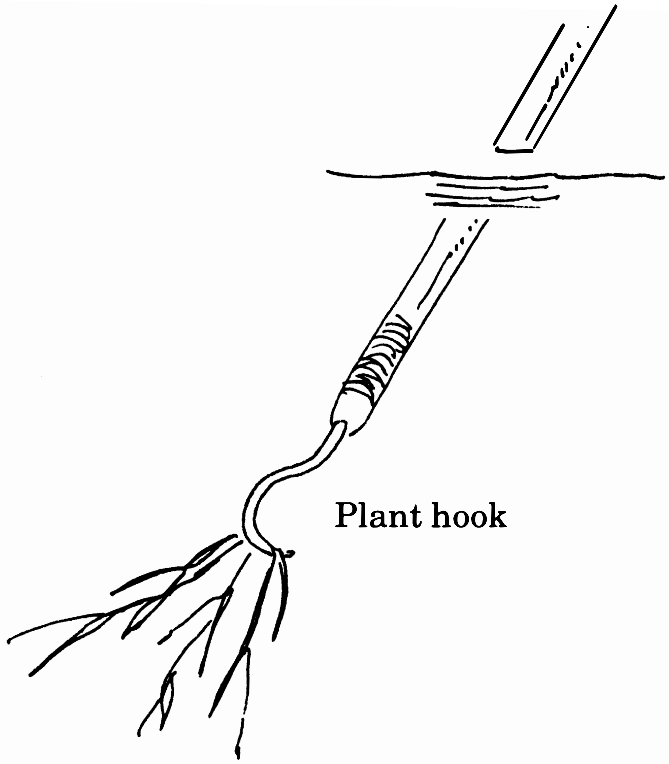


Appendix 3—Transparency

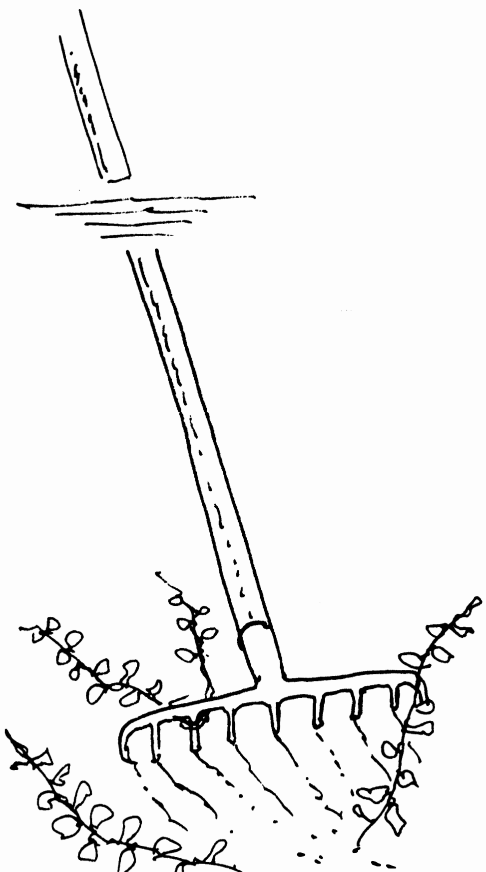
Sampling Aquatic Organisms



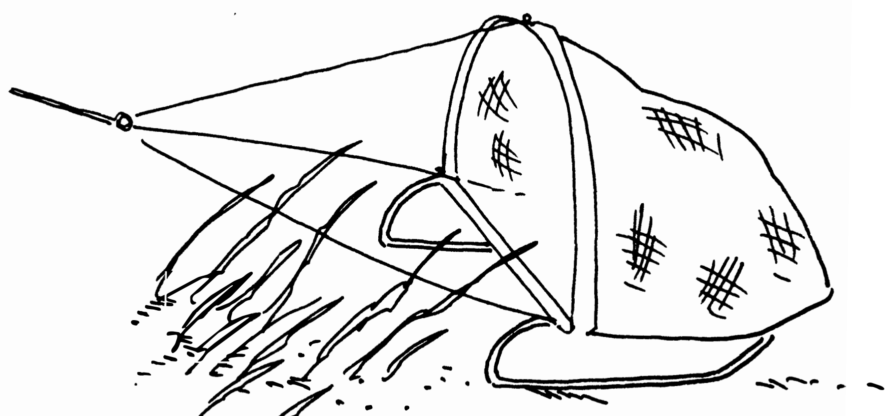
Plankton net



Plant hook



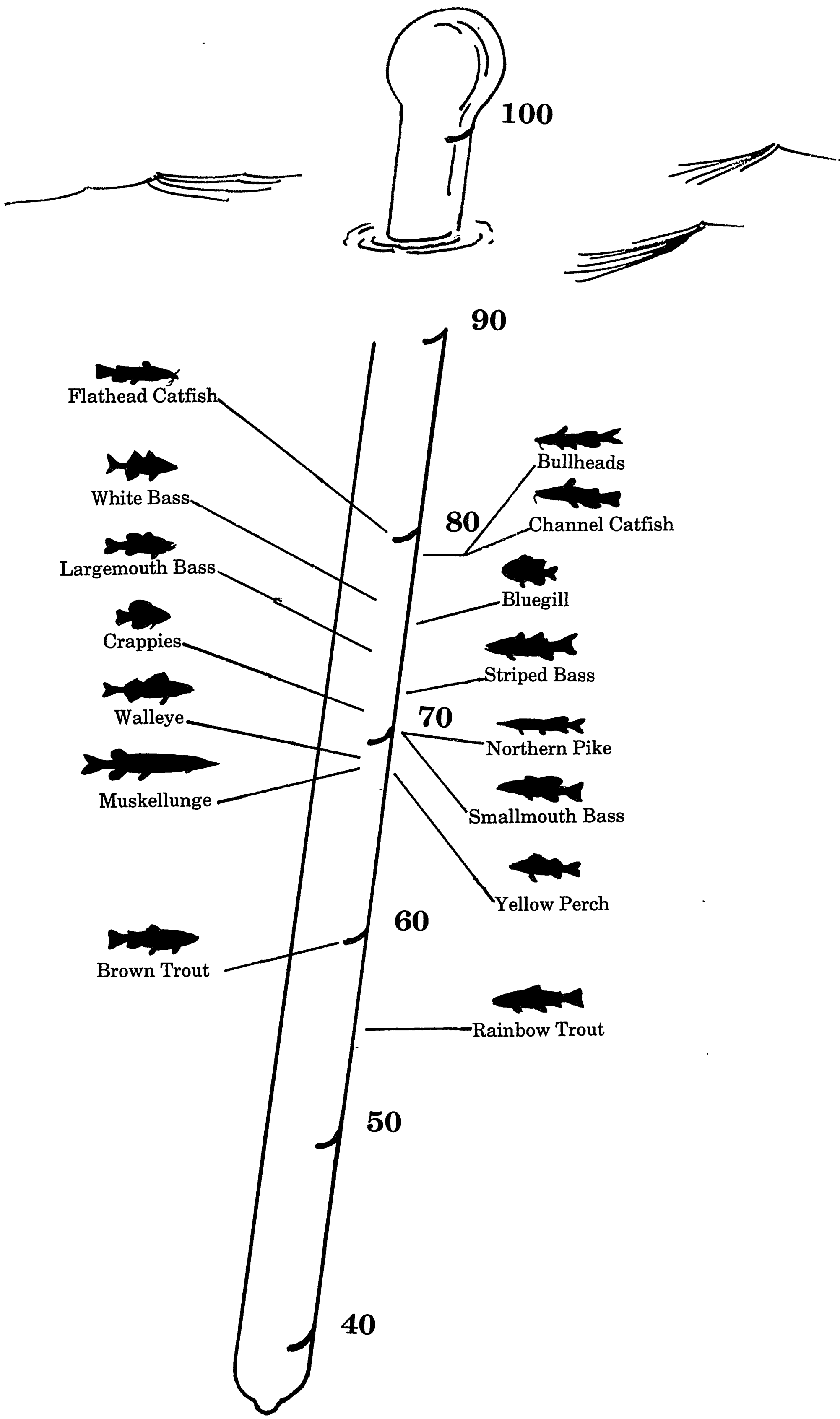
Plant rake



Bottom dredge

Appendix 4—Transparency

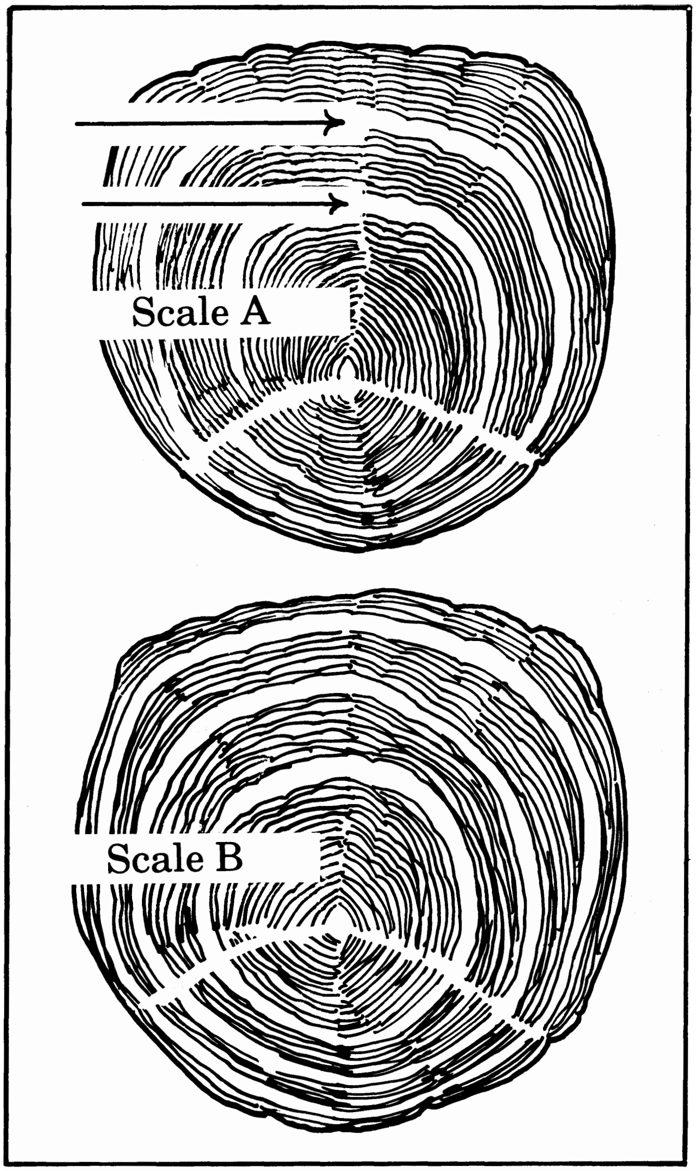
Tolerance of Fish to Temperature Fluctuations



70°-90°F = Warm water **60°-70°F = Cool water** **40°-60°F = Cold water**

Appendix 5—Transparency

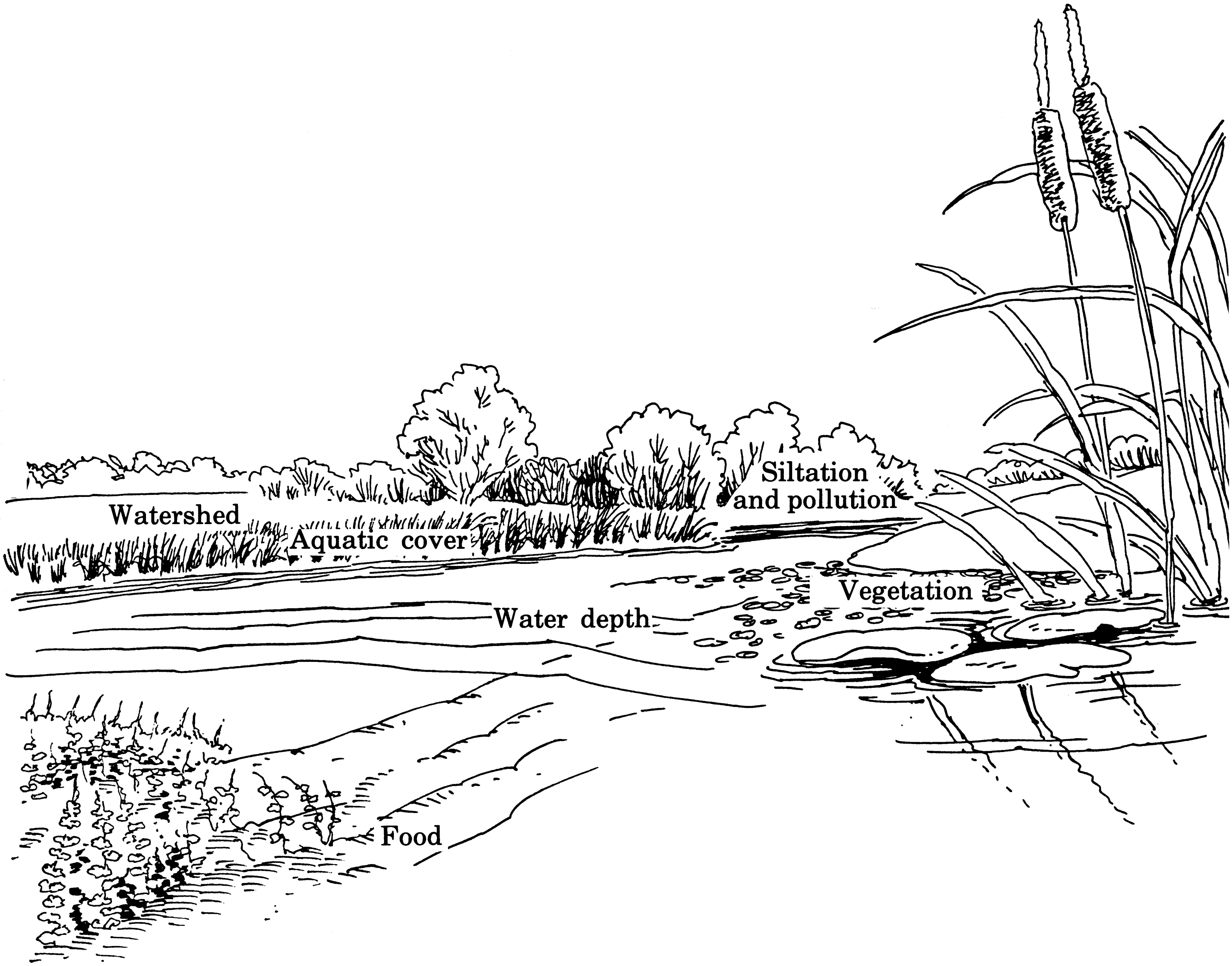
Aging Fish: Scale Method



Scales grow as the fish grows. In summer, when food is plentiful, the fish grows rapidly and so do the scales. In winter the growth is slower and scales do not grow as fast. This causes rings to form on the scales like those found in a tree trunk. Smaller rings are found in between the annual rings. Only the areas where the rings are very close together count as one year. Scale A has two growth rings marked. How many rings are shown in scale B?

Appendix 6—Transparency

Factors Affecting Water Quality



BEST Objectives Covered by this Instructional Unit

Reading/Language Arts

5. Use reference materials and sources to obtain information to solve personal problems.
12. Follow a set of written directions.
13. Interpret information presented in graphic or pictorial manner.
16. Use reference materials and sources (including human sources) to obtain information to solve personal problems.
17. Recognize the main idea and specific details in an oral presentation.
21. Follow oral or written directions to complete a process.

Mathematics

1. Add and subtract whole numbers in sample problems involving real-life situations.
2. Multiply and divide whole numbers in sample problems involving real-life situations.
6. Solve problems involving measures of length, area, and volume.
7. Solve problems involving measures of time and temperatures.
8. Interpret information from charts, graphs, tables, maps and scale drawings.
9. Solve sample problems by applying the concept of ratio and proportion.
11. Determine the average for given numerical data.
14. Use standard measuring devices to measure length, area, volume, weight, time, and temperature in common English and metric units.
15. Estimate results and judge the reasonableness of answers to computational problems.

Fisheries Management

Test Questions

1. List two reasons why fish are important to humans.
2. What are the four unique characteristics of water?
3. Draw a picture or diagram to illustrate three levels of energy transfer that take place in an aquatic system.
4. Give one example of how societal pressures can affect fisheries management.
5. What are four chemical factors in an aquatic system that affect fish and plant life?
6. How does water temperature affect water quality?
7. What are three physical factors in an aquatic system that affect fish and plant life?
8. Describe three functions of aquatic cover.
9. How can soil conservation practices improve water quality?
10. Describe three methods of sampling fish populations.
11. List five types of fishing regulations that help to control fish populations and sizes.
12. What is the major goal of fisheries management?

True-False

13. ____ Fishes are warm-blooded animals that have backbones, gills, and fins.
14. ____ Water temperature has no effect on water quality.
15. ____ Large predator fishes are the least numerous fishes in the total aquatic system.
16. ____ Chemical and physical analyses of water reveal an aquatic system's potential to support life.
17. ____ Fish extract oxygen from water by passing it through their lungs.
18. ____ The level of dissolved oxygen in an aquatic system can fluctuate from day to day.
19. ____ Carbon dioxide in an aquatic system is produced by the respiration of plants and animals.
20. ____ Turbidity and water color are the same thing.
21. ____ Electrofishing is a method of controlling fish populations in an aquatic system.
22. ____ The larger the watershed of an aquatic system, the less control the fisheries manager has over it.

Matching

23. ____ supersaturation	A. total mass of living organisms
24. ____ turbidity	B. maximum population an ecosystem can support

25. ____ anaerobiosis

26. ____ pH

27. ____ eutrophication

28. ____ biomass

29. ____ predator

30. ____ producer

31. ____ prey

32. ____ carrying capacity

33. ____ watershed

34. ____ impoundment

C. aging process of lakes whereby aquatic plants are abundant and waters are deficient in DO

D. artificial collection or storage of water

E. measure of acidity or alkalinity of a substance

F. animal that lives by capturing and devouring other animals

G. cloudy condition caused by suspended solids in water

H. condition where a solution has more solute dissolved than is normally possible

I. animal that is seized by another for food

J. land area that drains toward a water system

K. green plant

L. complete dissolved oxygen depletion of an aquatic system

Appendix 9

Fisheries Management

Answer Key

1. Fish are an important food source for humans and fishing is a major participatory sport in Missouri and the U.S.
2. Water can exist as a solid, liquid, or gas, becomes less dense than liquid water when it freezes, has a dissolving power greater than any other liquid, and acts as a buffer against extreme temperature changes.
3. Picture must include transfer of light energy from sun to producer organisms, from producer organisms to consumers, and from consumer to consumer.
4. Answers will vary.
5. Level of dissolved oxygen, carbon dioxide, pH level, fertility.
6. Chemical factors rely on water temperature. Dissolved oxygen content also is affected by water temperature.
7. Water temperature, turbidity, water color.
8. It provides food, shelter, protection, and concealment for fish and stabilizes shorelines.
9. Soil conservation will reduce turbidity which is detrimental to fish populations.
10. Electrofishing, gill nets, trap nets, mid-water trawls, meter nets, seines, observation, or use of chemicals.
11. Length limits (minimum length or slot length limit), creel limits, quota limits, harvest methods, and fishing seasons.
12. The major goal of fisheries management is to study each aquatic system and to devise and implement a management plan to produce and maintain good populations of quality-sized game fishes.
13. F
14. F
15. T
16. T
17. F
18. T
19. T
20. F
21. F
22. T
23. H
24. G
25. L
26. E
27. C
28. A
29. F
30. K
31. I
32. B
33. J
34. D

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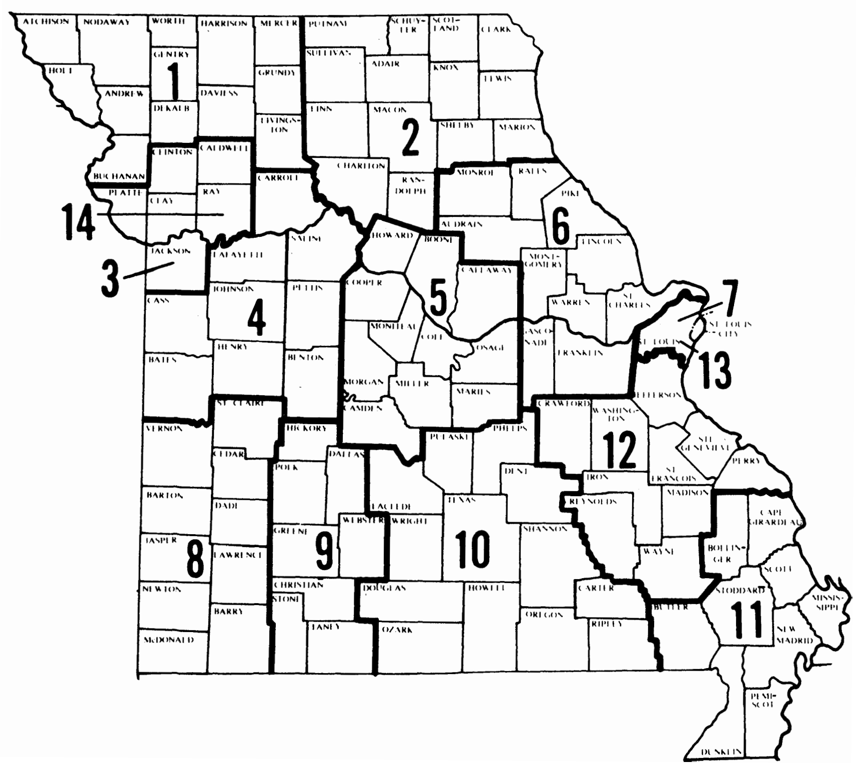
Conservation Education Consultants are available to provide conservation education assistance and offer courses and workshops in conservation.



Outdoor skills education specialists will assist you in obtaining materials and scheduling equipment and films that are available from the Department of Conservation. They also offer workshops to provide training in outdoor skills education. For the name and address of the outdoor skills education specialist serving your area, contact:

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NOTES: